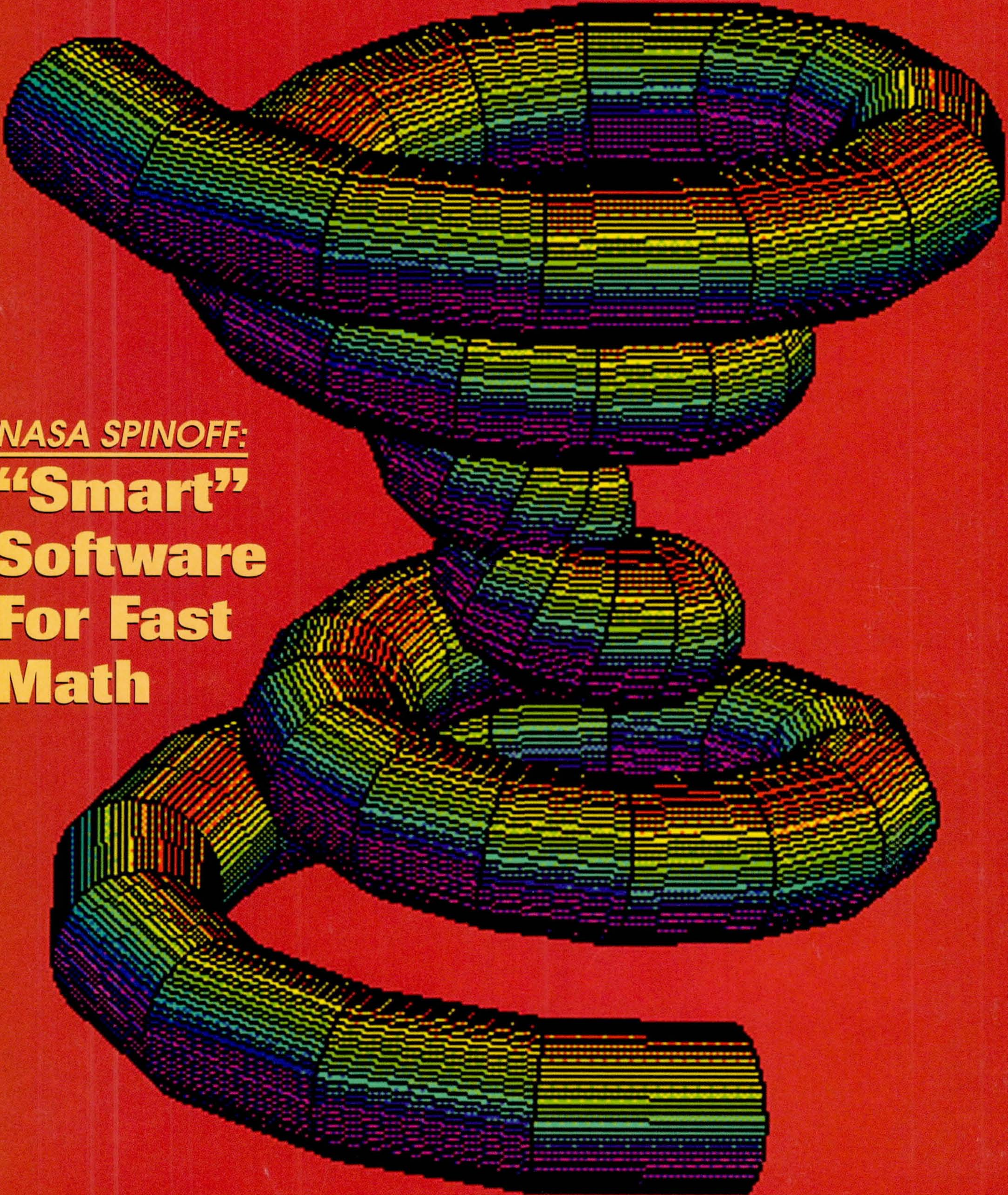
NASA Tech Briefs

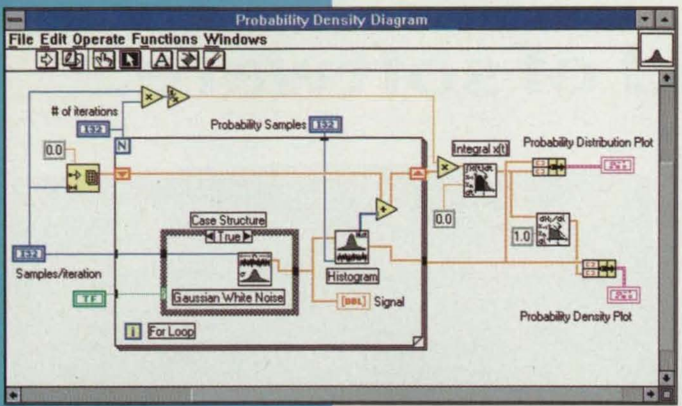
Official Publication of the
National Aeronautics and
Space Administration
September 1993 Vol.17 No. 9

Transferring Engineering
Technology to Over 200,000
Qualified Readers Throughout
Industry and Government

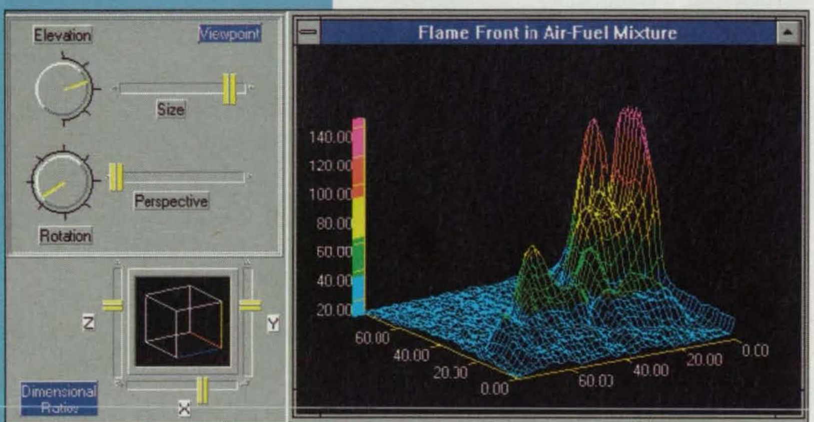


NASA SPINOFF:
"Smart" Software For Fast Math

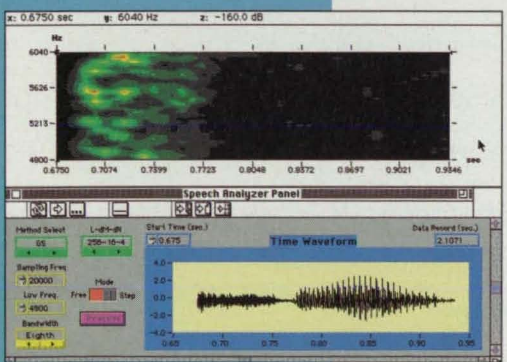
Draw Your Complete Analysis Solution with LabVIEW® Graphical Programming



LabVIEW is a complete graphical programming language.



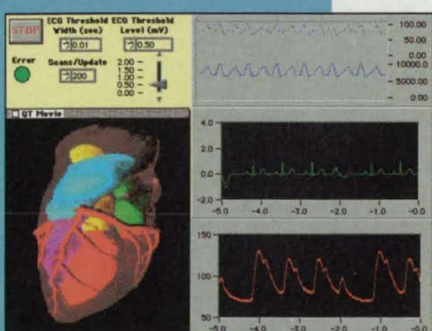
Surface plot of a flame front using LabVIEW and the SurfaceView toolkit.



Data courtesy of NIH.

Gabor Spectrogram
National Instruments

The Gabor Spectrogram displays a portion of the sentence "I take two people out for breakfast," computed and displayed with LabVIEW.



EKG signal and QuickTime heart video using LabVIEW.

Productive and Creative Methodology

Quickly develop programs for analysis, simulation, and algorithm development with the complete graphical programming language found in LabVIEW. It is more than a math calculator. LabVIEW has graphical constructs for While Loops, For Loops, and Case structures.

Advanced Visualization and Plotting

Rapidly create spectrograms, 2D plots, 3D plots, waterfall plots, strip charts, contours, and XY graphs with annotation, printing, and importing.

Powerful Mathematics

The award-winning LabVIEW Gabor Spectrogram algorithm for joint time-frequency analysis (JTFA) is an example of industry-leading innovation. In addition, LabVIEW has hundreds of analysis function blocks for signal processing, digital filters, statistics, and linear algebra. Add-on analysis toolkits include:

- image processing
- surface rendering
- PID control
- 3D plotting
- speech processing
- JTFA

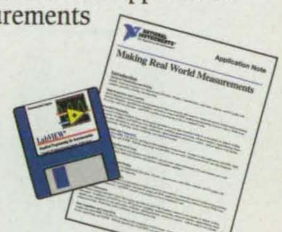
Beyond Analysis

Acquire data from GPIB, VXI, and RS-232 instruments and plug-in data acquisition boards. Connect to other applications with DDE, Apple Events, QuickTime, or TCP/IP. With the open design of LabVIEW, you can easily call programs from C and other languages. In addition, LabVIEW executes at speeds comparable to compiled C code.

Graphical User Interface (GUI) Tools

Easily create virtual instruments and interactively control real-world processes using the GUI controls and indicators built into LabVIEW.

Call for your **FREE** LabVIEW demo and the application note, "Making Real-World Measurements with Fast Fourier Transforms and LabVIEW."



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LabVIEW is now available on Windows, Sun, and Macintosh.

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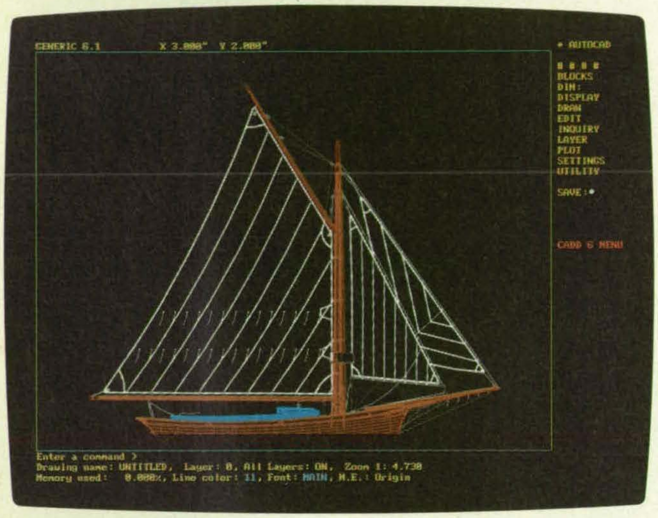
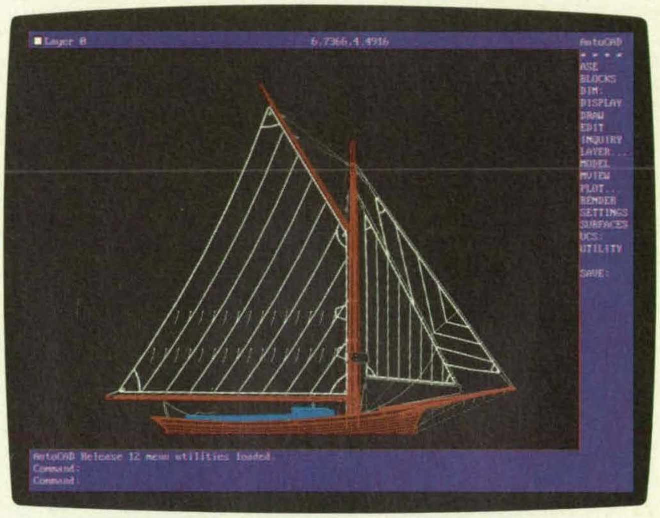
For More Information Write In No. 681

Why the makers of AutoCAD **strongly** recommend another brand of software.



New Generic CADD 6.1

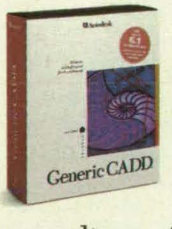


AutoCAD Release 12

Introducing Generic CADD 6.1.

The makers of AutoCAD® software recognize that not everyone needs AutoCAD's full-throttled power. That's why we recommend new Generic CADD® 6.1.

This latest version of Generic CADD software can now write AutoCAD.DWG files—the standard file format throughout the CAD world.



This upward compatibility from Generic CADD to AutoCAD lets you extend the power of CAD to anyone in your organization—even those not directly involved in the design process.

Of course, this latest version of Generic CADD delivers the extraordinary functionality and ease-of-use that have made it a three-time winner of the coveted *PC Magazine* Editors' Choice Award. And it's still only $495.

Generic CADD 6.1 is part of the Autodesk® family of design automation products. You'll find it at leading retail software centers. Or call us at 1-800-228-3601 and request Infopack #A108.

Autodesk.

September 1993
Volume 17 Number 9

Contents

NASA Tech Briefs

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Throughout Industry and Government

FEATURES

TECHNICAL SECTION

(continued on page 10)

MODEL #	FEATURES	APPLICATIONS
GP-KS152	■ Digital Signal Processing (DSP) ■ 1/2" Microlens CCD color microcamera ■ Electronic Light Control (ELC) ■ Minimum illumination 0.5fc ■ On-screen programmable features ■ 25 zone backlight compensation ■ Remote camera head 2/3" D x 1-1/2" L (without lens)	■ Endoscopic vision ■ Inspection ■ Nondestructive analysis ■ Laparoscopic vision
GP-KS202	■ 1/3" CCD color microcamera ■ 330 lines horizontal resolution ■ Auto tracing white balance ■ Remote camera head 1/2" D x 1-3/8" L (without lens)	■ Inspection ■ Nondestructive analysis ■ Machine vision ■ Endoscopic vision ■ Laparoscopic vision
GP-KS102	■ 1/2" CCD color microcamera ■ 430 lines horizontal resolution ■ Detachable head ■ Y/C (SVHS) and composite outputs ■ Auto gain control ■ Selectable TTL auto tracing ■ 12V DC operation ■ Camera head 2/3" D x 1-7/16" L (w/o lens)	■ Engines & machinery ■ Endoscopic vision ■ Nondestructive analysis ■ Surface mount inspection ■ Inspection ■ Laparoscopic vision
GP-MS112	■ 1/2" CCD B/W microcamera ■ 500 lines horizontal resolution ■ Detachable head ■ 12V DC operation ■ Camera head 2/3" D x 1-7/16" L (w/o lens)	■ Robotics ■ Machine vision ■ Inspection ■ Nondestructive analysis
GP-KR212	■ Digital Signal Processing (DSP) ■ 1/2" Microlens CCD color camera ■ 430 lines horizontal resolution ■ Minimum illumination 0.3fc at f1.4 ■ ELC and auto backlight comp. ■ 2H enhancer, aperture correction & knee circuitry	■ Microscopy ■ Measurement & inspection ■ Robotics ■ Surface mount inspection
GP-KR412	■ Same as GP-KR212 in addition to: ■ Full on-screen programming ■ 25 zone auto backlight comp. ■ Genlock capability	■ Microscopy ■ Measurement & inspection ■ Robotics
GP-KR402	■ 1/2" CCD color camera ■ 430 lines horizontal resolution ■ Variable speed electronic shutter ■ Y/C (SVHS) & composite outputs ■ 12V DC operation	■ Test & measurement ■ Inspection ■ Motion analysis
GP-MF552	■ Asynchronous electronic shutter ■ 2/3" CCD, 768 (H) x 495 (V) pixels ■ 570 lines horizontal resolution ■ Minimum illumination 0.05fc at f1.4 ■ External sync HD, VD	■ High speed analysis ■ Image processing ■ Process measurement
GP-MF502	■ 2/3" CCD, 768 (H) x 495 (V) pixels ■ 570 lines horizontal resolution ■ External sync HD, VD	■ Image processing ■ Process measurement
GP-MF702/D	■ 2/3" MOS image sensor 649 (H) x 491 (V) pixels ■ Asynchronous VD reset ■ Sq. pixels 13.5mm x 13.5mm with pixel clock in/out ■ Selectable scanning system (525 full line non-interlace) ■ Double speed scanning	■ Robotics ■ Inspection ■ Machine vision ■ High speed analysis
GP-MF200	■ 2/3" CCD, 768 (H) x 493 (V) pixels ■ 570 lines horizontal resolution ■ Remote head ■ External sync HD, VD	■ Factory automation ■ Robotics ■ Machine vision ■ Inspection

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READER SERVICE NUMBERS 610-620 CORRESPOND WITH MODELS LISTED IN CHART FROM TOP TO BOTTOM

Cameras shown with optional lenses.

Contents *(continued)*

On the cover:

This parametric equation plot was created using Mathcad®4.0, interactive mathematical software from MathSoft Inc. The latest update features SmartMath™, an intelligent interface that reviews a user's problem and then proposes a method to solve it. SmartMath was developed using NASA's C Language Integrated Production System (CLIPS), software for the creation of rule- and object-based expert systems. See the story on page 14.

Computer graphic courtesy MathSoft, Inc.

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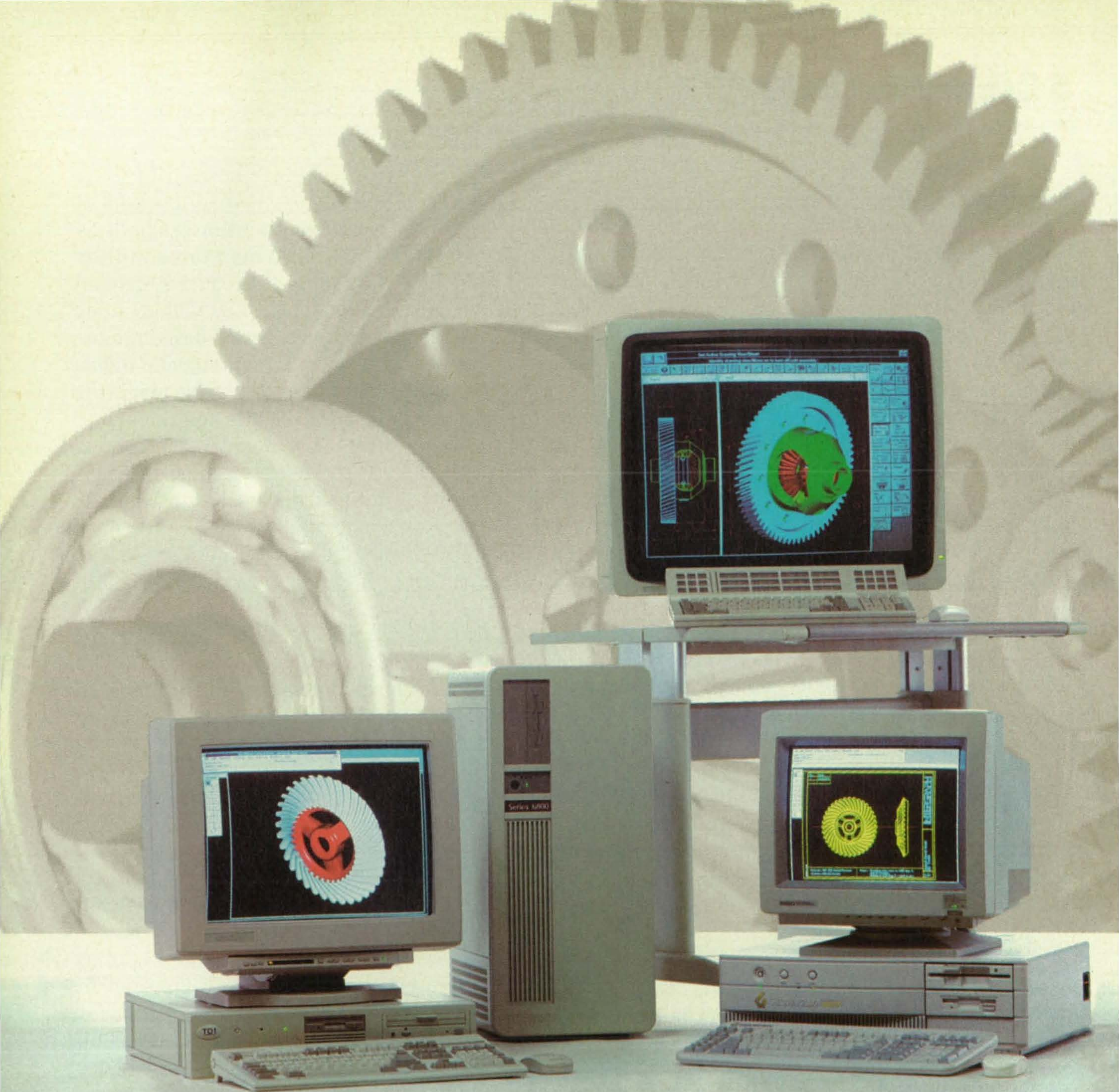

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Mission Accomplished

Through the technology transfer process, many of the systems, methods, and products pioneered by NASA are reapplied in the private sector, obviating duplicate research and making a broad range of new products and services available to the public.

When you were in math class and needed help, you asked the professor. When calculating a troublesome engineering equation today, you call a mathematician. Or, if you're using the latest in math software, you can simply ask your computer for assistance.

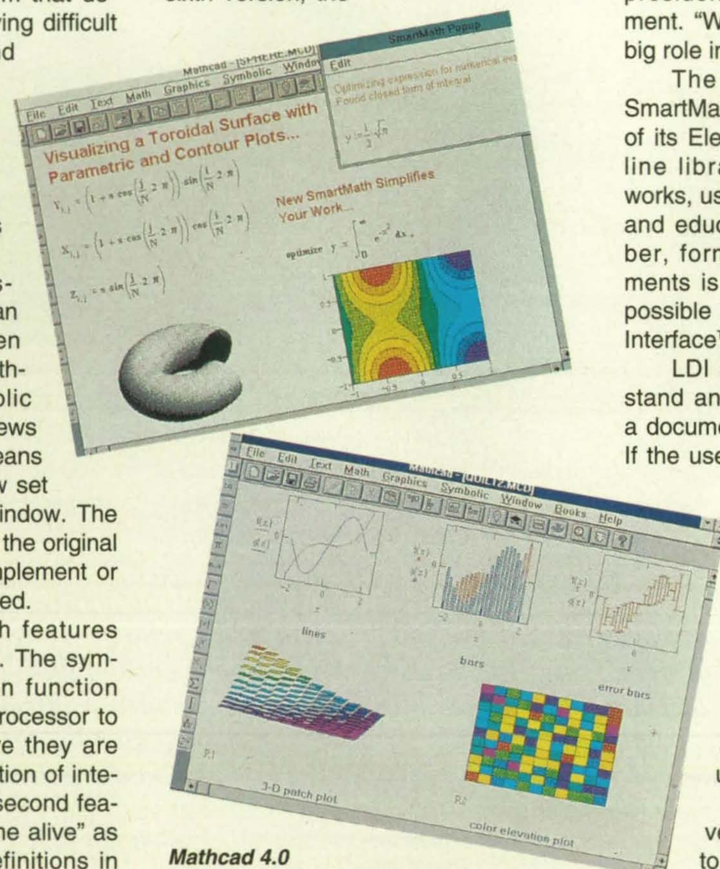
Mathcad® 4.0, released in March by MathSoft Inc., Cambridge, MA, incorporates an expert system that determines a strategy for solving difficult mathematical problems and then provides the solution. The new capability, called SmartMath™, extends the interactive nature of Mathcad, which automatically updates results as variables or formulas are changed.

SmartMath, a rules-based processor, provides an intelligent interface between the user's problem and Mathcad's numeric and symbolic capabilities. SmartMath reviews a problem, determines a means to solve it, and writes a new set of equations in a pop-up window. The results then are delivered to the original document. The user can implement or override SmartMath as desired.

Two basic SmartMath features are included in version 4.0. The symbolic/numeric optimization function uses Mathcad's symbolic processor to simplify expressions before they are computed, including evaluation of integrals and derivatives. The second feature allows symbols to "come alive" as well, using all previous definitions in the document to evaluate symbolic expressions. It recomputes symbolic results whenever any of the equations on which they depend are changed.

SmartMath was implemented using the C Language Integrated Production System (CLIPS), software developed at NASA's Johnson Space Center that provides an environment for the construction of rule- and object-based expert systems. CLIPS dates back to 1984, when engineers in Johnson's Artificial Intelligence Branch (now the Software Technology Branch) recognized the need for expert systems technology employing a conventional computer language such as C. Until that time, nearly all expert system software tools had used LISP as the base language, which severely limited their use on standard computers.

In 1986, CLIPS was made available outside of NASA. Now in its sixth version, the system offers a unique combination of portability, extensibility, capabilities, and low cost. Available through NASA's Computer Software Management and Information Center (COSMIC), CLIPS has over 4000 users, including every NASA field center and military branch, numerous federal bureaus, universities, and private companies. Diverse applications include a diagnostic and maintenance system for the Cray-3 supercomputer, an automated scheduling system for semiconductor manufacturing, and a tool for compiling legal documents.



Mathcad 4.0 enables users to interact with every number and symbol in a wide range of graphs and plots.

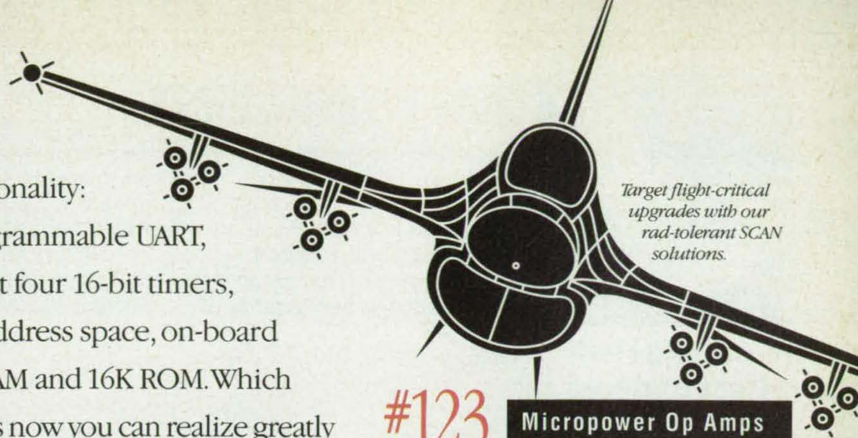
"CLIPS was a big enabler for MathSoft—it was small and fast and designed for embedding," said Allen Razdow, MathSoft's chairman and vice president of research and development. "We expect it's going to play a big role in Mathcad from now on."

The company plans to deliver SmartMath-aware add-ons in the form of its Electronic Handbooks™—an on-line library of technical reference works, user guides, solution templates, and education materials. Every number, formula, and plot in the documents is "live" and interactive, made possible by MathSoft's Live Document Interface™ (LDI) technology.

LDI allows a computer to understand any number or equation within a document as a mathematical object. If the user changes a numerical value or parameter in an equation, the answer is automatically recalculated. If a term is added or deleted, the equation recalculates itself and every subsequent equation or graph in the document. No programming knowledge is needed to create or manipulate the formulas or graphs.

In addition to SmartMath, version 4.0 has been updated to run in the Windows 3.1 environment as a 32-bit application using Microsoft's new WIN32S libraries. At 32 bits, it's twice as fast and users can manipulate virtually unlimited data arrays at one time. Also available for use in DOS, Macintosh, and UNIX systems, Mathcad has an estimated 600,000 users worldwide. ❑

For more information about the software described in this article, contact MathSoft Inc., 201 Broadway, Cambridge, MA 02139-1901. Tel: 617-577-1017 or 1-800-628-4223; Fax: 617-577-8829.



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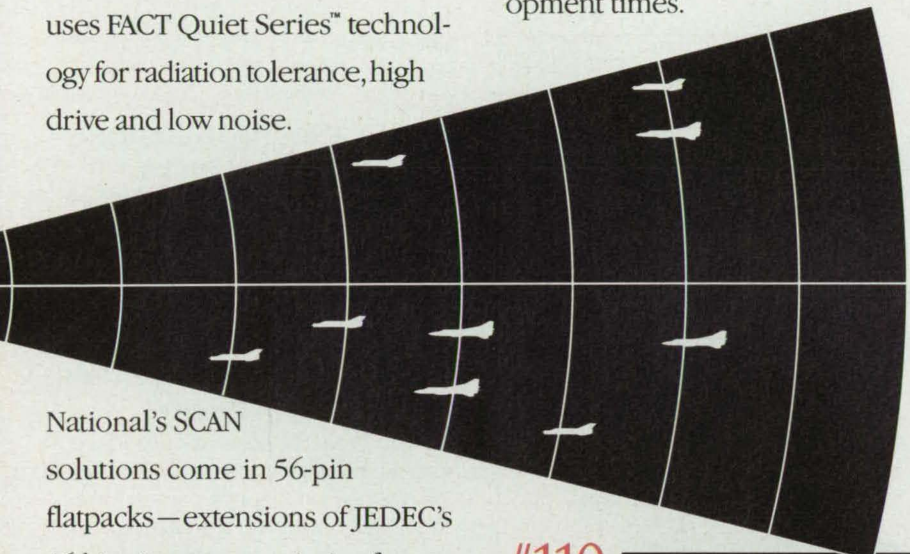

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New Product Ideas

New Product Ideas are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Technology Utilization Office of the sponsoring NASA center (see page 24). NASA's patent-licensing program to encourage commercial development is described on page 24.

Improved Hall-Effect Sensors for Magnetic Memories

Improved Hall-effect sensors offer the combination of adequate response (±10 mV) and high speed needed for use in micromagnet/Hall-effect random-access memories.
(See page 31.)

Book Holder and Page Turner for the Elderly and Handicapped

A quadriplegic can turn pages with little of no assistance thanks to a device that accommodates a variety of publication formats, whether book, magazine, or newspaper.
(See page 106.)

Dual-Latching, Solenoid-Actuated Tube Valve

A tube-type shutoff valve is actuated by a concentric solenoid. The solenoid holds the valve in position until it is changed electrically or manually.
(See page 108.)

Deep Skirt Would Confine Oil Spilled in Water

Two types of skirts are proposed to contain oil spills. A deeper model would be deployed immediately around a leaking ship or platform; a shallower model would be used over a larger area if the leak has spread.
(See page 110.)

Transpiration Control of Aerodynamics Via Porous Surfaces

Effects of porosity would be modified to enhance the performances of aircraft. A device based on this concept would be extremely lightweight, mechanically simple, extremely adaptable, and occupy little volume in the vehicle.
(See page 112.)

Compact Robotic Vehicle

A miniature robotic vehicle implements a new fork-wheeled mobility concept to traverse extremely rough terrain. The vehicle weighs 4 kg, is 0.4 m long, and can climb over obstacles as large as 60 percent of its length.
(See page 121.)

Slip-Cast Superconductive Parts

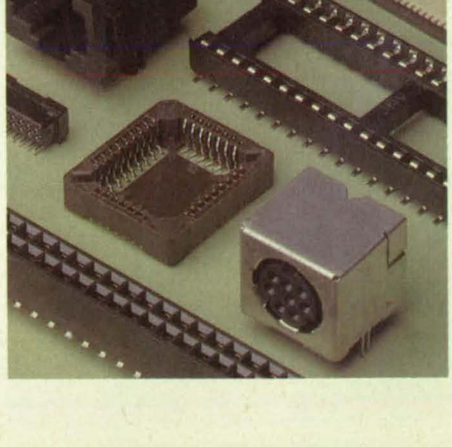
Complex shapes are fabricated by a nonaqueous slip-casting process. Machining, which introduces cracks and flaws into brittle superconductive ceramics, is eliminated.
(See page 124.)

How to stay out of the rough in surface mount technology.

Surface mount interconnects are a whole new game in technology. And as in most new games, a little help from the pros makes life easier.

Each surface mount application presents its own problems requiring a unique solution. Our experience in design and manufacturing can help guide you through the options, giving you a clearer understanding of what you can (and can't) do to integrate surface mount interconnects into existing or new products.

We'll show you the variations in form you can choose from – from through-hole compatibles to new, ultra-fine-pitch SMT



products. We'll make sure the contact configuration and foot design you choose are right for the physical requirements of your system. We'll help determine optimum holddown type, based on how your product will be assembled and used. And we'll show you how the right combination can answer design needs and fit successfully into production.

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We've outlined below NASA's Technology Transfer Network—named the participants, described their services, and listed the individuals you can contact for more information relating to your specific needs. We encourage you to make use of the information, access, and applications services offered.

How You Can Access Technology Transfer Services At NASA Field Centers:

Technology Utilization Officers & Patent Counsels—Each NASA Field Center has a Technology Utilization Officer (TUO) and a Patent Counsel to facilitate technology transfer between NASA and the private sector.

If you need further information about new technologies presented in *NASA Tech Briefs*, request the Technical Support Package (TSP). If a TSP is not available, you can contact the Technology Utilization Officer at the NASA Field Center that sponsored the research. He can arrange for assistance in applying the technology by putting you in touch with the people who developed it. If you want information about the patent status of a technology or are interested in licensing a NASA invention, contact the Patent Counsel at the NASA Field Center that sponsored the research. Refer to the NASA reference number at the end of the Tech Brief.

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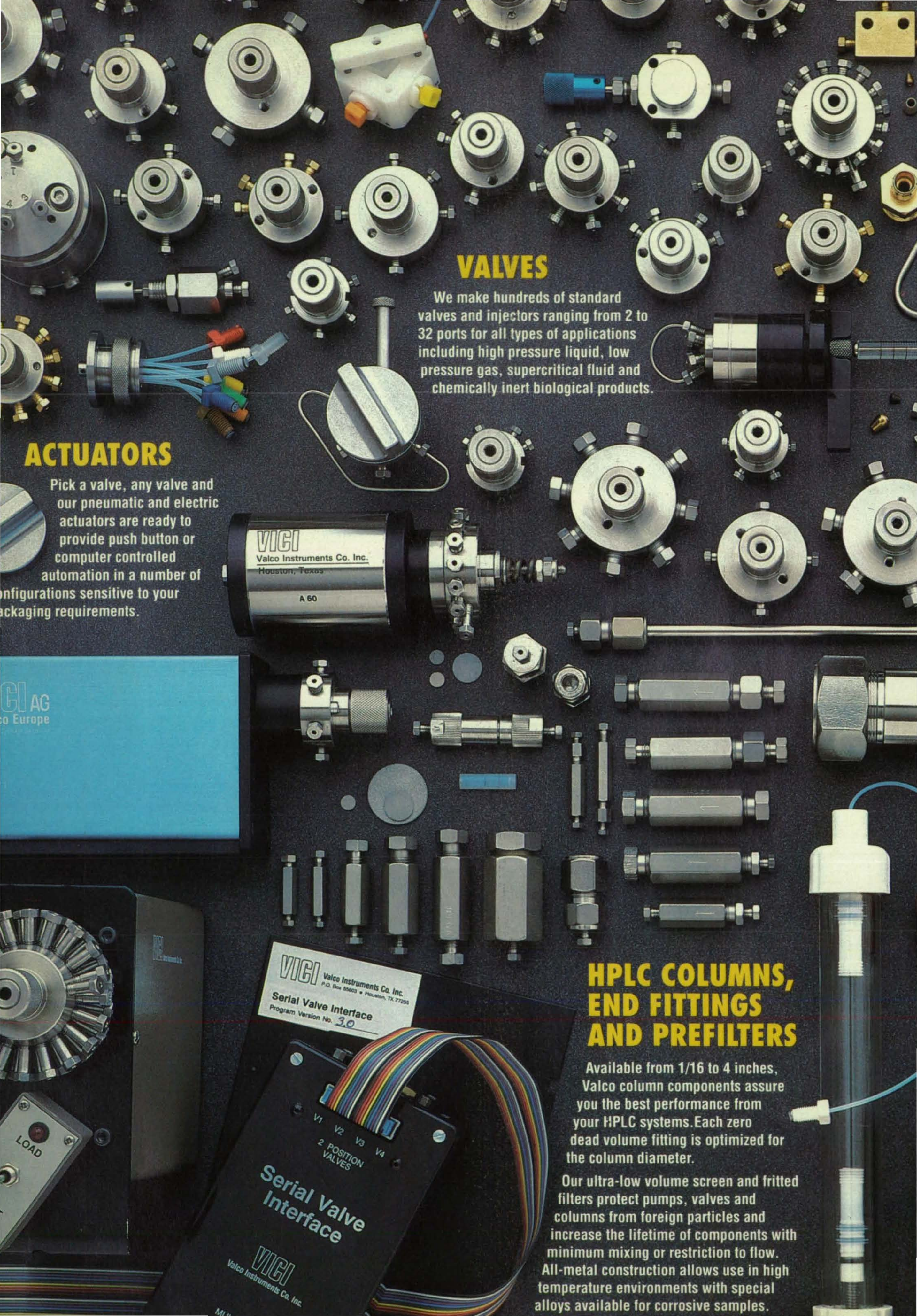

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Compact Circuit Preprocesses Accelerometer Output

The circuit can be incorporated into the accelerometer case.

Lyndon B. Johnson Space Center, Houston, Texas

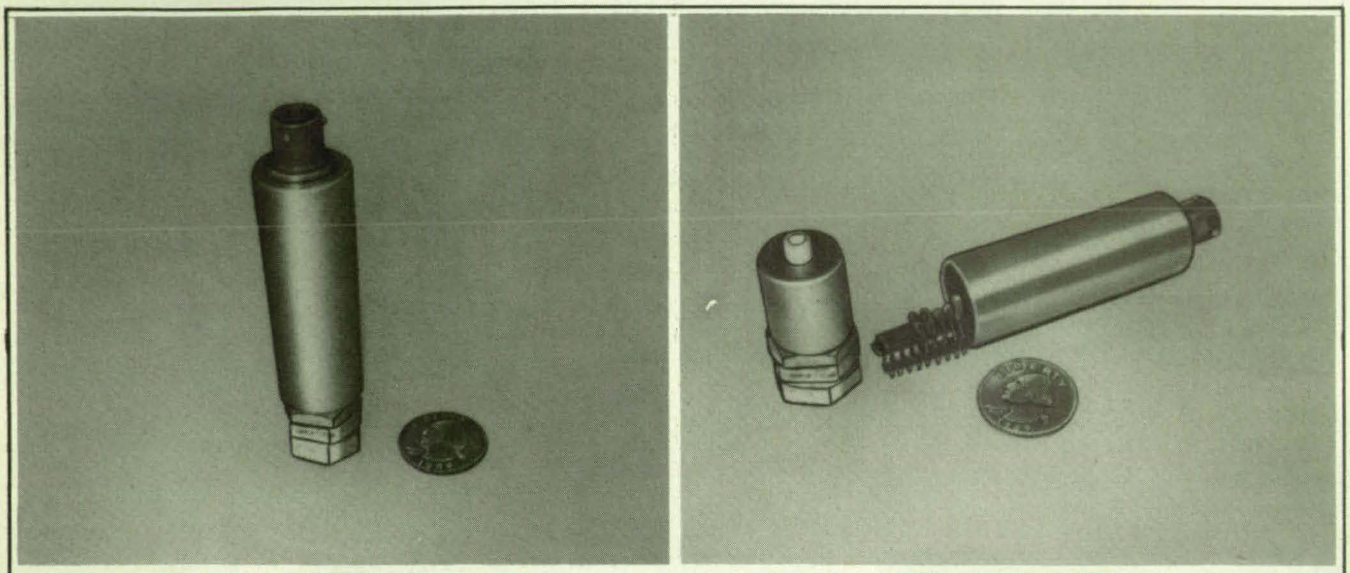

Figure 1. The **Accelerometer and Signal-Preprocessing Circuit** fit together in a compact package.

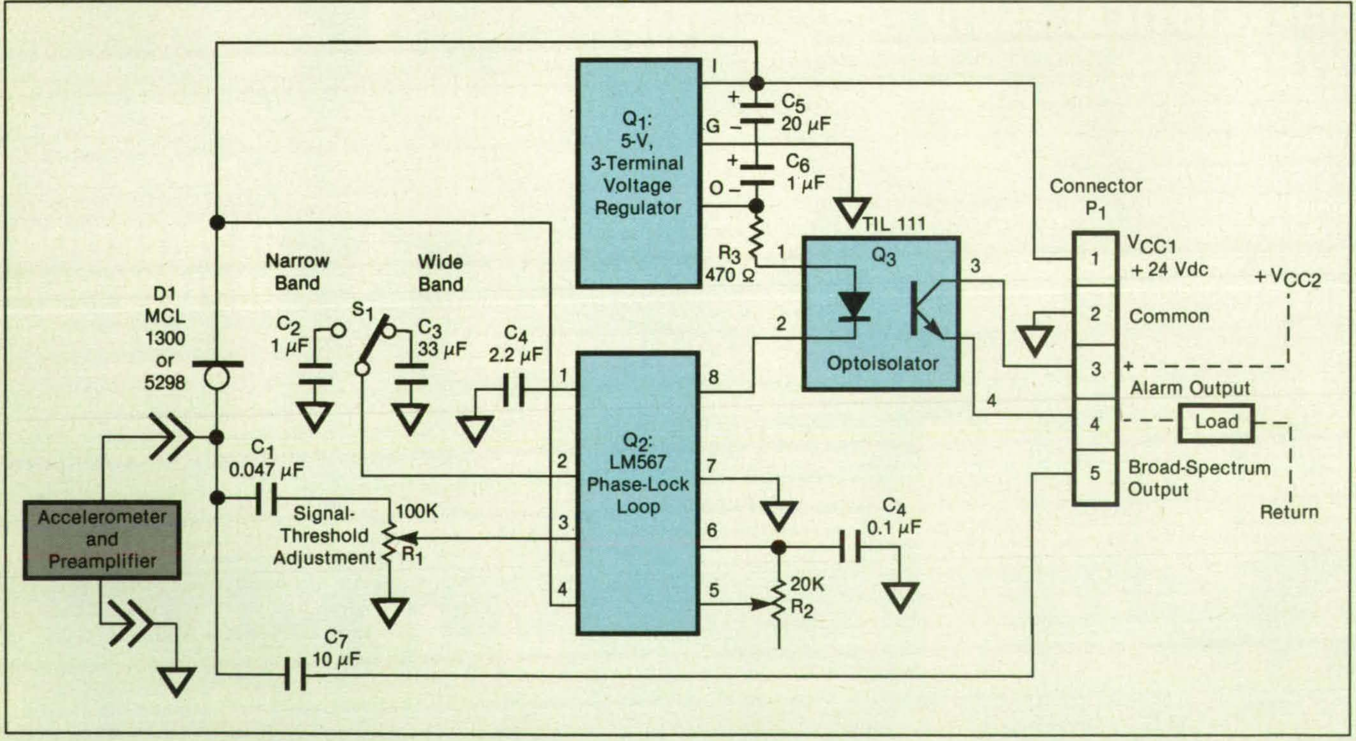

Figure 2. The **Signal-Preprocessing Circuit** is made of commercial integrated circuits and other conventional components.

A compact electronic circuit transfers dc power to, and preprocesses the ac output of, an accelerometer and an associated preamplifier. The circuit can be incorporated into the accelerometer case during initial fabrication or retrofit onto a commercial accelerometer, as shown in Figure 1. The circuit is made of commercial integrated circuits and other conventional components; it could be made smaller by use of micrologic and surface-mount technology.

The circuit can be adjusted to select the middle frequency (between 1 and 500 kHz) and either of two widths of a passband, within which the accelerometer output is to be monitored to detect a signal indicative of a phenomenon of interest. Such a phenomenon might be, for example, the undesired vibration, at a frequency within the passband, of a rotating shaft or bear-

ing. The circuit can also be adjusted to set a trip level.

A signal that rises above the trip level triggers a pulse. If the signal cycles and corresponding pulses repeat at a rate within the passband, the circuit generates an alarm signal in the form of closure of the transistor switch on the output side of an optoisolator. Thus, one of the overall functions of the circuit is to translate the analog signal from the accelerometer to a transistor/transistor-logic-level output that is compatible with a monitor-and/or-control computer, all without the complexity of the usual analog-to-digital-converter circuitry that might otherwise be needed to effect such a function.

As shown in more detail in Figure 2, power at 24 Vdc is supplied to this circuit package through pins 1 and 2 of connector P_1. The 24-Vdc power is fed to the accelerometer and its preamplifier through field-effect diode D_1, which regulates current. The 24-Vdc power is also fed to Q_1, which is a three-terminal, 5-Vdc regulator that supplies power to the rest of this preprocessing circuit.

The broadband dynamic signal from the accelerometer is fed into this circuit through C_1. It is also bypassed to pin 5 of P_1 via C_7. The trip level is set by adjusting potentiometer R_1 on the basis of accelerometer-calibration data. Potentiometer R_2 is adjusted to set the middle of the passband at the desired frequency, which is read by connecting a frequency counter to pin 6 of phase-lock loop Q_2. (R_2 and C_4 are the components that govern this frequency.)

The width of the passband around the selected middle frequency is selected by use of switch S_1. Typically, at a middle frequency of 1,000 Hz, the passband is approximately 75 Hz wide in the "narrow" mode and up to approximately 300 Hz wide in the "wide" mode. In the "narrow" mode, approximately 50 incoming signal cycles within the passband must be accumulated before Q_2 puts out an alarm signal. In the "wide" mode, nominally only 10 to 15 cycles are required to generate an alarm signal. This "pulse-counting" feature inherent to Q_2 prevents transient pulses within the passband from triggering an alarm.

The alarm output of Q_2 consists of the sinking of an open collector (at pin 8), which is connected to pin 2 of the optoisolator. The output of the optoisolator is connected to pins 3 and 4 of P_1 and can be used to gate relays, solid-state switches, computer-interrupt circuits, and the like to turn off or otherwise control machinery. If it is desired to have a latched output detection of a fault (as indicated by an alarm signal), an optical silicon-controlled rectifier could be used and could be reset by use of an external reset switch or by dropping the load. The optoisolator feature prevents unwarranted or inadvertent shutdown or other control functions caused by electrical ground loops, of which the user may not be aware in practice.

This work was done by Richard J. Bozeman, Jr., of **Johnson Space Center**. *For further information,* ***write in 2*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center [see page 24]. Refer to MSC-21951.

Improved Readout for Micromagnet/Hall-Effect Memories

Additional transistors eliminate current shunts that could cause readout errors.

NASA's Jet Propulsion Laboratory, Pasadena, California

Two improved readout circuits for micromagnet/Hall-effect random-access memories are designed to eliminate current shunts that introduce errors into the outputs of older readout circuits. A micromagnet/Hall-effect random-access memory is one in which micromagnets are arranged in rows and columns, the datum in each memory cell is represented by the state of magnetization of its micromagnet, and this state of magnetization (and thus the datum) is read out by use of the Hall-effect sensor associated with the given micromagnet.

In a typical readout circuit of an older design (see Figure 1), the voltage leads of the Hall sensors in each column are connected in series, so that only one sensing amplifier is needed. The current leads of the Hall sensors on each row are also connected in series. Each row is controlled by two transistors, one at each end of the row. To read the content of cell 21, for example, one applies the high logic-level voltage to the conductors RS_2 (row select 2) and CS_1 (column select 1), so that transistors Q_3, Q_4, and Q_5 are turned on. With Q_3 and Q_4 turned on, a current flows through the Hall sensors in cells 21 and 22, so that both sensing amplifiers A_1 and A_2 produce signals. However, because Q_6 remains turned off, only the signal from A_1 is passed by Q_5 to the output terminal.

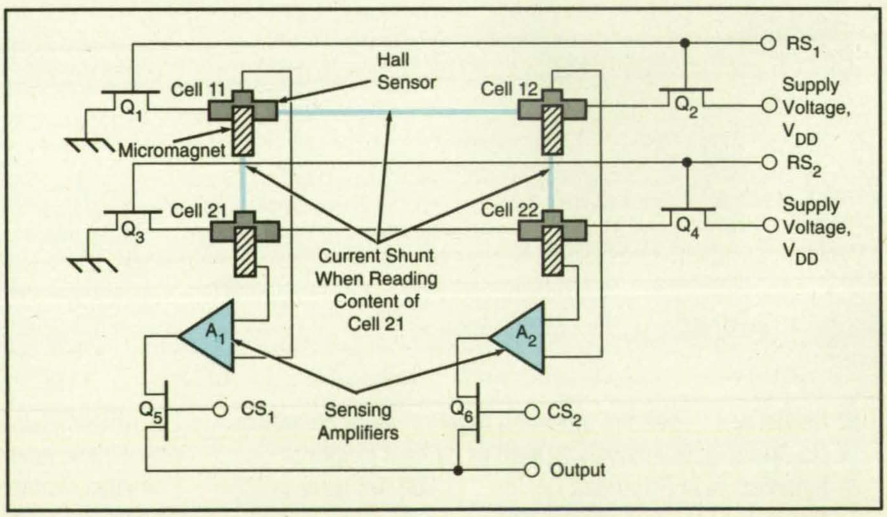

Figure 1. This **Readout Circuit** for a 2×2 micromagnet/Hall-effect random-access memory is subject to shunting of currents along undesired paths, with resultant erroneous contributions to the output voltage.

In this example, the undesired current shunt and the resulting output error arise as follows: When Q_3 and Q_4 are turned on to let the current flow through cells 21 and 22, the current can also flow from the upper voltage lead of cell 22 through cell 12, then through cell 11 back to cell 21. This current shunt introduces voltage drops across the voltage leads of cells 11 and 12. These voltage drops are added to the Hall voltages developed across cells 21 and 22, and thereby become parts of the input presented to sensing amplifiers A_1 and A_2, resulting in an error in the output voltage.

The improved circuits (see Figure 2) incorporate additional switching transistors to isolate the Hall sensors as needed, eliminating the current shunts. In the circuit shown at the top, each Hall sensor is isolated by two transistors, one on the current lead on each side; for example, cell 21 is isolated by transistors Q_7 and Q_8. To read informa-

tion from cell 21, one applies the high logic-level voltage to CS_1 and RS_2. Current then flows from V_{DD} through Q_1, Q_8, cell 21, and Q_7 to ground. Transistor Q_4, being off, prevents the current from flowing through cell 11 to cell 21. Transistor Q_3, being off, prevents the current from flowing through cell 11 to ground. Thus, there is no current shunt problem. Furthermore, although transistors Q_9 and Q_{10} are also turned on, no current flows through cell 22 because Q_2 remains turned off.

In the circuit shown at the bottom, the current leads of the Hall sensors in the same row are connected in series. Suppose that the voltages on RS_2 and CS_1 are made high to read out the content of cell 21. Transistors Q_4, Q_5, and Q_6 are turned on, sending current through cells 21 and 22. Transistors Q_1 and Q_2 remain off, preventing cell 11 from shunting cell 21, and transistors Q_2 and Q_3 prevent cell 12 from shunting cell 22. The output from sensing amplifier A_1 is passed through Q_{11} to the output terminal. The advantage of this design is that fewer isolating transistors are needed. The disadvantage is that only a fraction (half in this example) of the supply voltage is available to generate the Hall voltage in each cell.

This work was done by Jiin-chuan Wu, Henry L. Stadler, and Romney R. Katti of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 79*** *on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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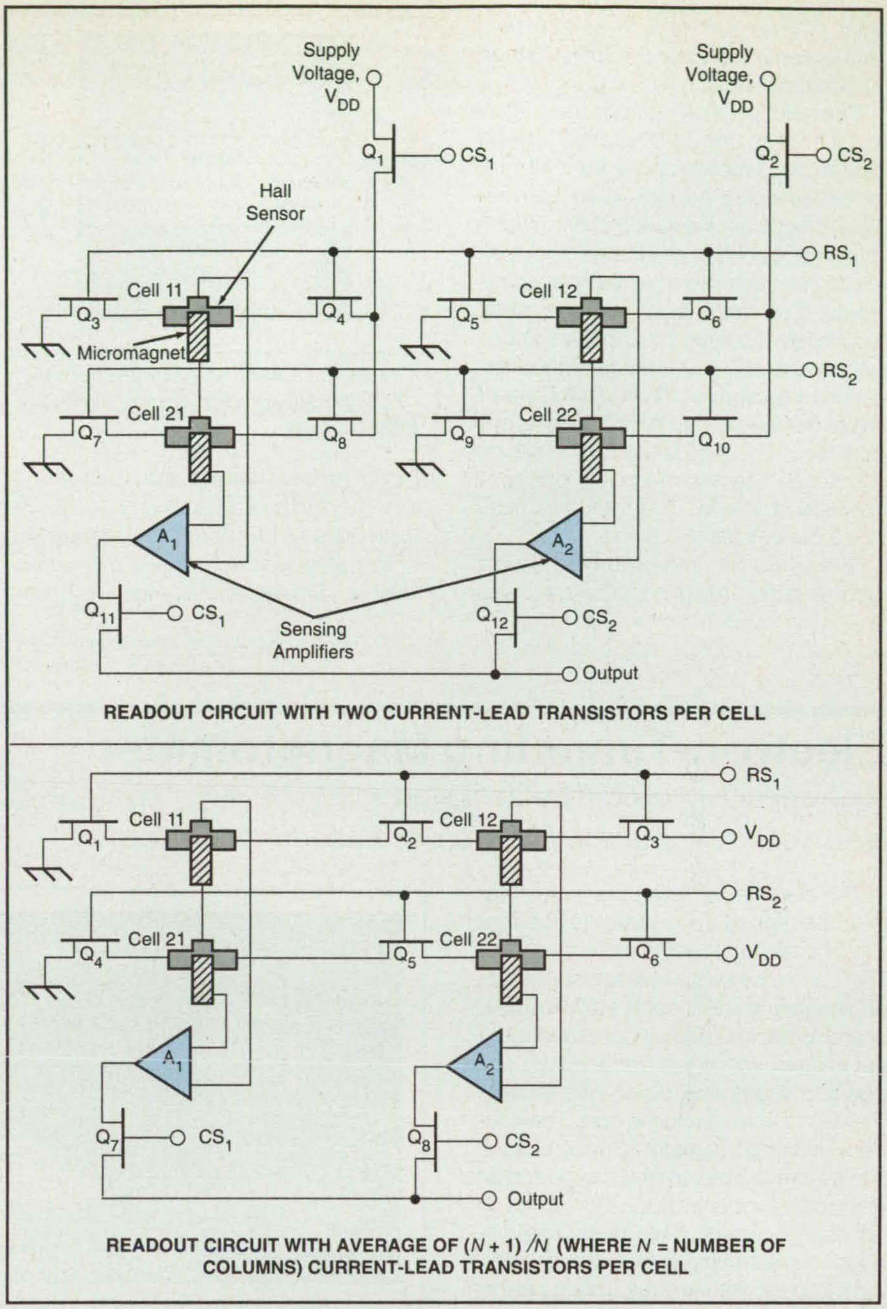


Figure 2. These **Improved Readout Circuits** incorporate additional transistors that are turned off as needed to eliminate undesired current shunts.

Improved Hall-Effect Sensors for Magnetic Memories

High-electron-mobility sensor films are deposited on superlattice buffer (strain) layers.

NASA's Jet Propulsion Laboratory, Pasadena, California

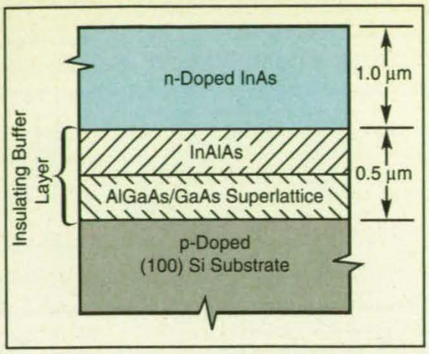
Improved Hall-effect sensors offer the combination of adequate response (±10 mV) and high speed needed for use in micromagnet/Hall-effect random-access memories. Specifically, a Hall-sensor film for a memory cell must satisfy two requirements: (1) it must have an electron mobility $\geq 10^4$ $cm^2/s{\cdot}V$ to ensure the desired sensitivity and response, and (2) its thickness must be made less than 1 μm to limit the readout current and the size of the transistor needed to switch the readout current. Another reason to limit the thickness is to reduce the step-coverage problem in the fabrication of the memory.

The Hall-effect material chosen for use in the improved sensors is InAs. In single-crystal form, this material has an electron mobility of 3.3×10^4 $cm^2/s{\cdot}V$; of course, in polycrystalline form it has a much smaller electron mobility. The problem in fabricating a sensor is to deposit a high-quality (nearly perfect single crystal) film of InAs on a silicon substrate. But single-crystal InAs cannot be formed directly on Si because the lattice con-

stant of InAs is 6.0585 Å — 11.6 percent greater than the 5.4308-Å lattice constant of Si.

The solution is to smooth the transition between the mismatched crystal lattices by depositing the InAs film by molecular-beam epitaxy on an intermediate, electrically insulating buffer (strain) layer that consists of sublayers of materials that have intermediate lattice constants. (The buffer layer must be made electrically insulating to prevent short-circuiting of the Hall voltage). In the example of the figure, the first sublayer of the buffer layer — an AlGaAs/GaAs superlattice — is deposited on the silicon substrate. The second buffer sublayer consists of InAlAs. The total thickness of the buffer layer is 0.5 µm.

The GaAs film in a prototype device fabricated according to this concept was found to have an electron mobility of 1.1×10^4 cm²/s•V. The device produces the required ±10-mV, fast readout signal.



The **Buffer Layer** enables the formation of a high-quality InAs layer by molecular-beam epitaxy.

This work was done by Jiin-chuan Wu, Henry L. Stadler, and Romney R. Katti of Caltech and Y.C. Chen and Pallab K. Bhattacharya of the University of Michigan for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 22*** *on the TSP Request Card.*

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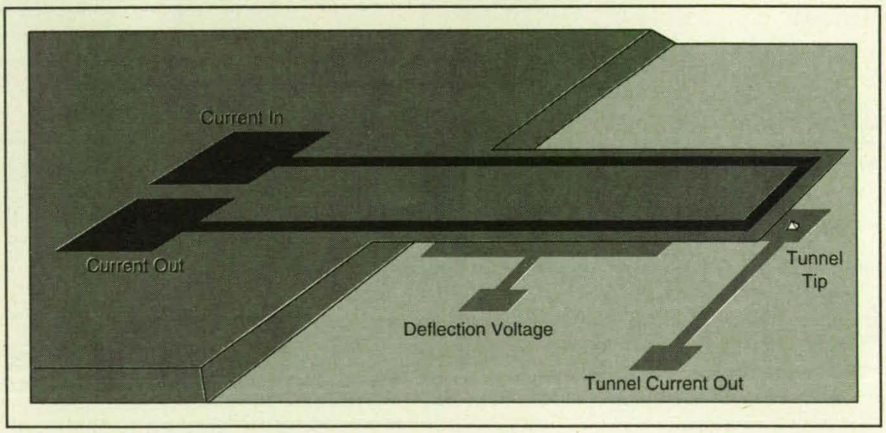
Electron-Tunneling Magnetometer

High sensitivity would be achieved without bulky, expensive cooling equipment.

NASA's Jet Propulsion Laboratory, Pasadena, California

The electron-tunneling magnetometer is a conceptual solid-state device that would operate at room temperature, yet offer sensitivity comparable to state-of-the-art magnetometers such as flux gates, search coils, and optically pumped magnetometers, with greatly reduced volume, power consumption, electronics requirements, and manufacturing cost. The electron-tunneling magnetometer consists of a miniature cantilever, which supports an electrically conductive loop that carries an oscillating current. The interaction between current-carrying loop and an external magnetic field (via the Lorentz force) produces a vibration in the position of the cantilever. This vibration is detected by an electron-tunneling displacement transducer, similar to the transducers in scanning tunneling microscopes. We have built and tested tunneling displacement transducers that can detect vibrations with amplitudes less than 0.001 Å, where single atoms have diameters of approximately 1 Å.

As presently planned, the device (see figure) would occupy an area of about 1 cm by 1 cm on a silicon wafer. The device is fabricated by silicon micromachining, a process that uses lithographic and etching techniques developed for microcircuit fabrication, but which are used for the fabrication of micromechanical structures in this case. Using these techniques, it is possible to fabricate arrays of sensors for field-gradient measurements and to integrate the electronics with the sensor.



The **Electron-Tunneling Magnetometer** would be micromachined from a silicon wafer and would use a tunneling displacement transducer to detect magnetic forces on a cantilever-supported current loop.

The loop-shaped cantilever is made by doping the surface of the wafer and then electrochemically etching away the surrounding and underlying silicon. The resulting cantilever may be as thin as 1 µm, resulting in extreme flexibility and good sensitivity to magnetic forces. The current loop is deposited on top of the cantilever, and the tunneling contact on the bottom.

A pyramid-shaped tunneling tip is formed by lithography and etching of the silicon wafer under the cantilever, and made conductive by evaporative deposition of gold films. A second electrode surrounds the tip and is used to control the position of the cantilever by electrostatic forces. When operated in force-feedback mode, the electrostatic forces balance the magnetic forces.

In initial operation, oscillating current is made to flow in the loop, and voltage is applied to the tip and deflection electrodes. When the deflection voltage is large enough to deflect the cantilever to within tunneling range of the tip, the feedback circuit is activated. The feedback circuit measures the tunneling current, compares it with a reference value, and applies correction voltages to the deflection electrode so as to minimize the errors. In the presence of an external magnetic field, the cantilever will experience an oscillating force, which is balanced by an oscillation in the deflection voltage. The amplitude of the deflection-voltage oscillation is proportional to the component of the external field that is in the plane of the loop and perpen-

dicular to the end of the cantilever.

An estimation of the magnetic field sensitivity based on the measured force sensitivity of the tunneling transducers built at JPL has been carried out and indicates that sensitivities better than 10^{-6} gauss/$\sqrt{\text{Hz}}$ can be obtained using this design. A proof-of-concept prototype is currently being built.

This work was done by William J. Kaiser, Thomas W. Kenny, and Steven B. Waltman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 24*** *on the TSP Request Card.*

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Refer to NPO-18493, volume and number of this NASA Tech Briefs issue, and the page number.

Microelectronic Chips for Radiation-Dose Tests

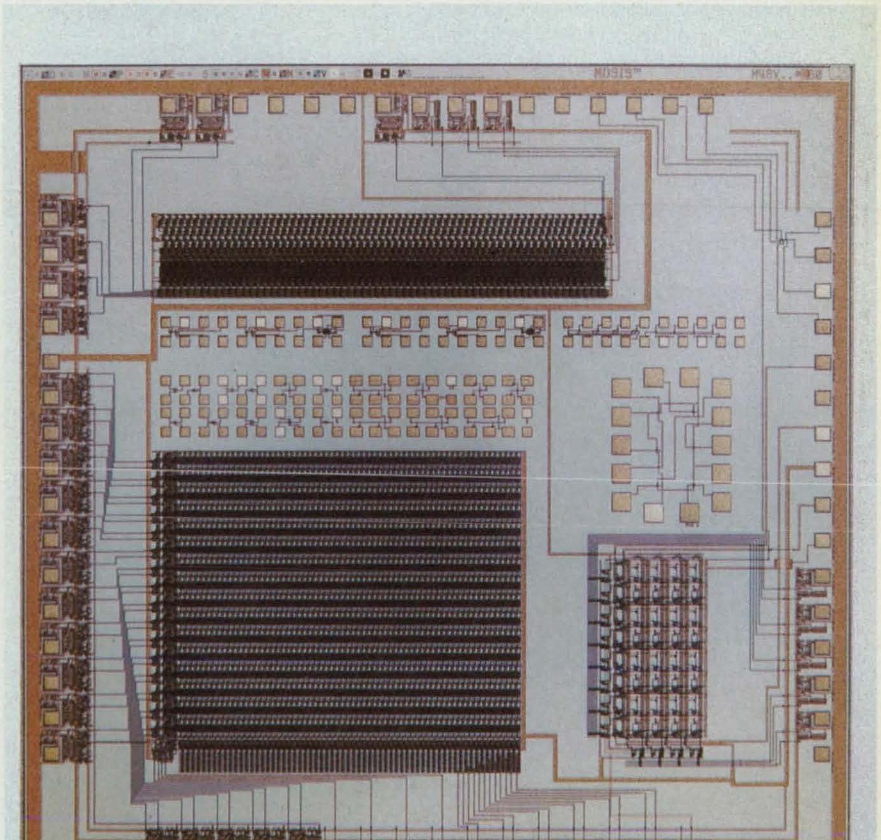
Integrated circuits yield data on effects of ionizing radiation.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure illustrates a custom-made single-chip complementary metal-oxide semiconductor (CMOS) integrated circuit designed to reveal the effects of ionizing radiation on itself and similar integrated circuits. An assembly of 12 such chips stacked 3 deep (and, therefore, shielded from ionizing radiation to various degrees) was flown in 1990 aboard the Combined Release and Radiation Effects Satellite. One potential terrestrial use for circuits like this one might be safety-oriented monitoring of ionizing radiation at nuclear powerplants, nuclear-waste sites, and the like.

The circuit chip measures 6.8 by 6.8 mm and is housed in a 64-pin dual-in-line package. It contains three main parts: (1) a matrix of 29 addressable metal oxide/semiconductor field-effect transistors (MOSFET's) for use in characterizing the effects of the total dose of radiation on threshold voltages and other MOSFET parameters, (2) a timing sampler for measurement of the radiation-induced degradation in the propagation of signals, and (3) a 1-kbit static random-access memory for evaluation of single-event upsets.

In the spacecraft tests, the MOSFET's were biased in the OFF state, which is the worst-case bias condition, when their electrical parameters were not being measured. A total of 120 data points were measured for each transistor: the drain current was measured at 10 settings of drain voltage and 12 settings of gate voltage, each ranging from 0 V to a supply voltage of 5 V. Temperature sensors placed near the integrated circuits provided data to compensate for the effects of temperature fluctuations, so that the effects of radiation could be isolated in the analysis of the MOSFET parameters. The temperature correction was an integral part of a mathematical model used to extract threshold voltages and conduction factors from the saturation regions of the MOSFET characteristics.



This **Integrated Circuit** provides measurements that can be analyzed to assess the effects of ionizing radiation on CMOS circuits.

One of the interesting conclusions drawn from the measurements was that the threshold-voltage damage factors of the MOSFET's on the middle chips in the stacks were about one-thousandth of those estimated from ground tests in which chips were irradiated by a Co^{60} source, while those of the outer chips were about equal to those estimated from the ground tests. It has been conjectured that the reason for this discrepancy is that the irradiation of the middle chips was dominated by protons, while the irradiation of the outer chips was dominated by electrons, and that Co^{60} tests tend to produce results similar to those of irradiation by electrons.

This work was done by Martin G. Buehler, Yu-Sang Lin, Kevin P. Ray, and Martin M. Sokoloski of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 33*** *on the TSP Request Card. NPO-18720*

MMIC Receiver for Water-Vapor Radiometer

MMIC water-vapor radiometers (WVR) have potential for relatively inexpensive mass production.

NASA's Jet Propulsion Laboratory, Pasadena, California

Figure 1 is a block diagram of a prototype 31-GHz receiver made of monolithic microwave integrated circuits (MMIC's). This MMIC receiver demonstrates a single channel of a 2-channel (31-GHz and 20-GHz) water-vapor radiometer system. From these two independent measurements, one can compute the water-vapor and liquid-water contents of the atmosphere.

This development is motivated by the need to overcome the disadvantages of existing water-vapor radiometers; namely, high cost, large size, and thermal instability of calibration (caused partly by large size). The miniaturization afforded by MMIC's should enhance the thermal stability and thus the stability of calibration of the water-vapor radiometer. MMIC's have great potential for mass production at relatively low cost. This should facilitate widespread use of MMIC water vapor radiometers in meteorology and aviation — to be deployed at several global sites to improve the capability of general circulation models and at airports to monitor icing conditions by measuring supercooled liquid water in clouds.

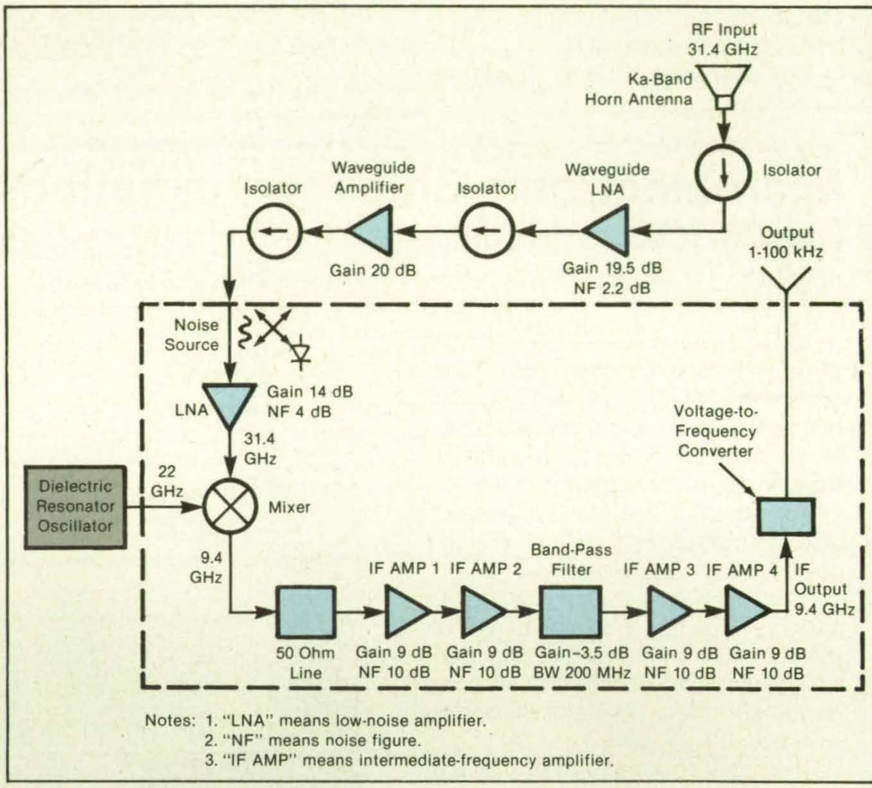


Figure 1. This **MMIC Receiver** puts out a signal, the frequency of which is proportional to the brightness temperature of the sky at an input frequency of 31 GHz.

The prototype radiometer accepts a bandwidth of noise power at 31 GHz, either from an antenna or from its built-in noise source, which is used for calibration. It converts the input signal to an intermediate frequency (IF) at 9 GHz and detects the IF signal. The measured bandwidth of the MMIC WVR is 200 MHz, centered at 30.8 GHz. The detected signal is processed into a pulse stream whose frequency varies from 0 to 100 kHz and is proportional to the brightness temperature of the sky in the input-frequency band.

Figure 2 shows the individual MMIC modules and the MMIC water vapor radiometer assembly. These modules were integrated, along with a commercial 22 GHz dielectric-resonator oscillator and an antenna, onto a heat-sink carrier.

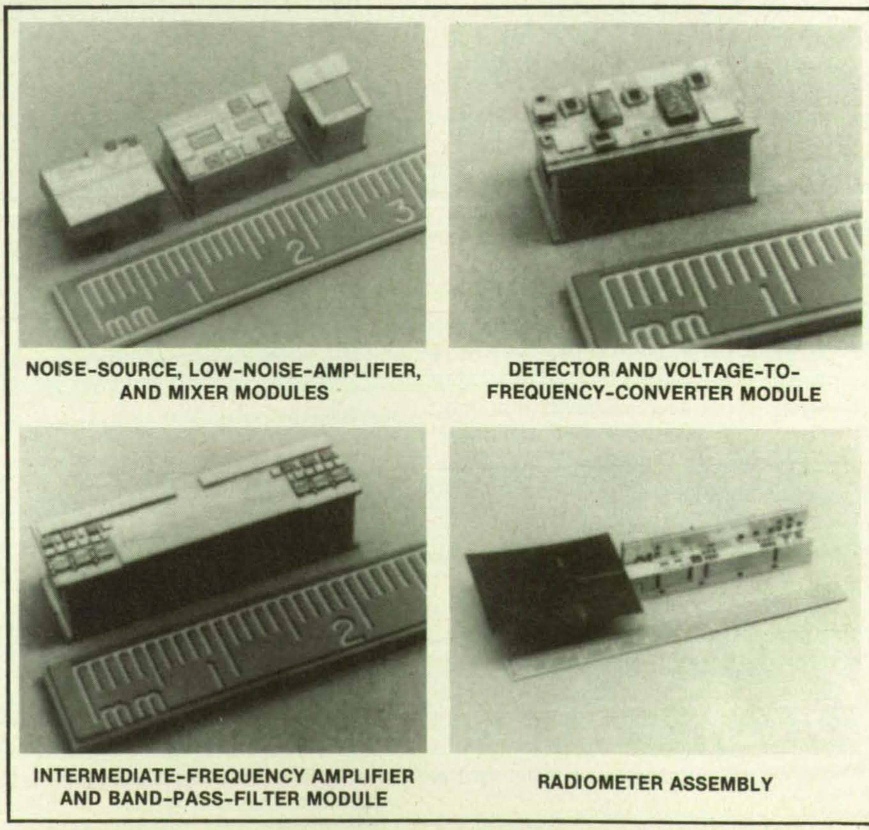


Figure 2. The **Prototype Receiver** was built in modules to facilitate testing.

This work was done by Lin M. Sukamto, Thomas W. Cooley, Michael A. Janssen, and Gary S. Parks of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 101*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office [see page 24]. Refer to NPO-18713.

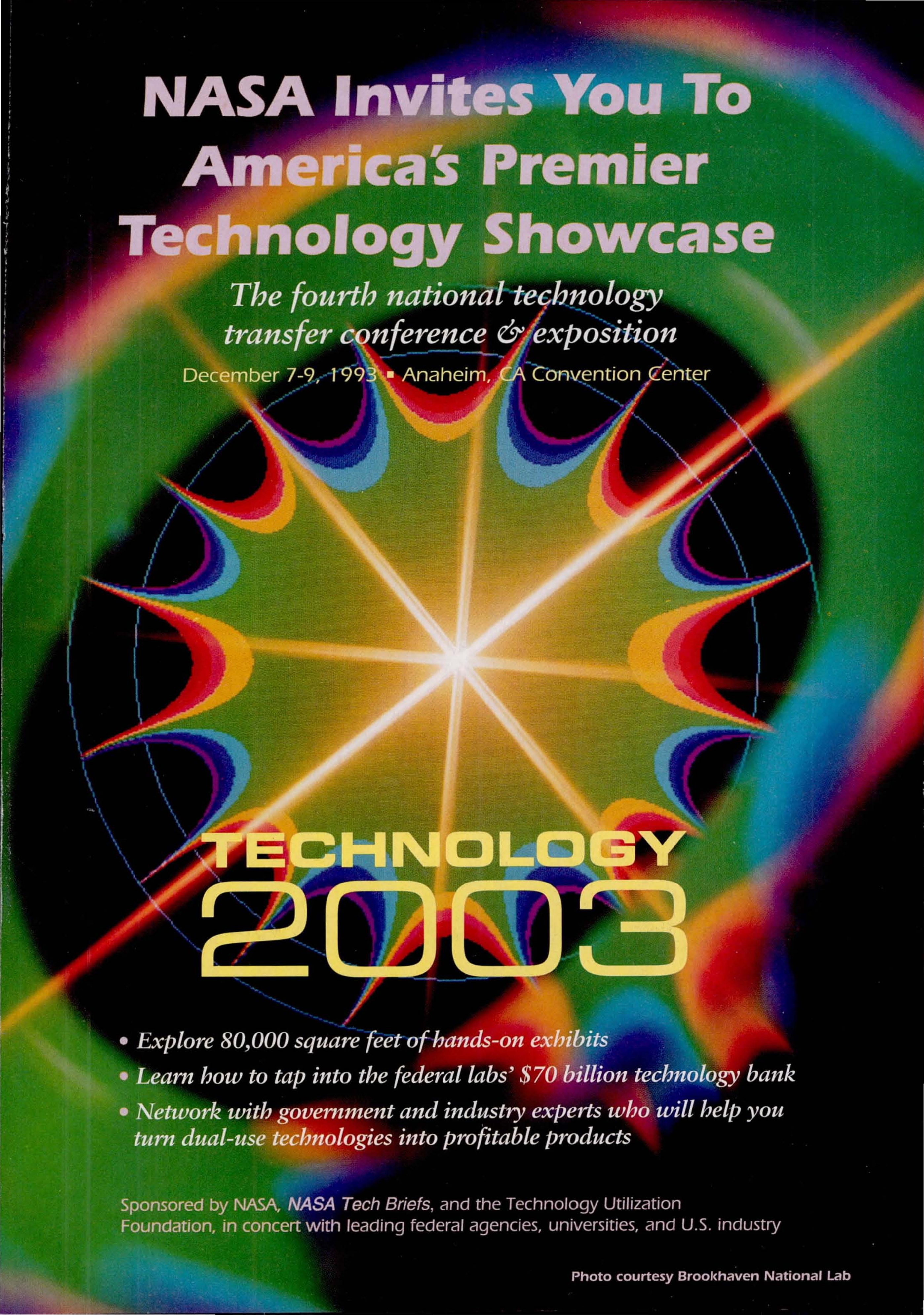


Photo courtesy Brookhaven National Lab

America's Best Inventions...Its Premier Researchers...Its Top Technology Managers...All In One Place, At One Time

TECHNOLOGY 2003

Dec. 7-9, 1993 • Anaheim Convention Center

More than a conference, more than a trade show, Technology 2003 is a vital business resource that will put you in direct contact with the leading technology developers and tech transfer experts in U.S. federal laboratories, industry, and universities. Technology 2003 specifically can help you:

- Find ready-made solutions to engineering problems
- Discover ideas for new products and processes
- Improve your manufacturing/production operations
- Locate joint venture partners
- Broaden your knowledge and expertise

TECHNOLOGY 2003 is your key to unlocking the incredible wealth of "dual-use" technologies in the nation's 700+ federal labs. The three-day event will feature:

EXHIBITS A "who's-who" of govt. labs and high-tech companies will showcase their latest technologies and products available for license or sale in the 80,000 square-foot exhibits halls (see pages D-E);

SYMPOSIA Over 100 symposia presentations — by researchers and managers from NASA, the departments of Defense, Energy, Agriculture, Interior, and other key agencies and their contractors — will spotlight commercially-promising inventions and advanced processes in critical areas driving U.S. and world growth markets (pages F-O);

PLENARY-DEFENSE CONVERSION Find out how you can benefit from the government's multi-billion dollar effort to convert aerospace/defense technologies to new commercial markets (page F);

WORKSHOPS Information-packed workshops will include a primer on successfully doing business with the government; opportunities for international technology transfer and partnering; and a special session on new precision casting techniques for the U.S. foundry industry (pages J, M);

AWARDS BANQUET The Fourth Annual Technology Transfer Awards Dinner, to be held December 8 at the Anaheim Marriott, offers an unparalleled opportunity to network with government and industry leaders (page M). Seating is limited and expected to fill quickly, so reserve your tickets early.

You can attend dozens of meetings this year and spend countless hours searching for new ideas to help your business grow...or you can invest three days at Technology 2003 and discover — in one place, at one time — the best technology America has to offer. Make a solid investment in your future: register today to attend Technology 2003 using the form on page P.

TECHNOLOGY 2003

Program At A Glance

	TUESDAY, DECEMBER 7	WEDNESDAY, DECEMBER 8	THURSDAY, DECEMBER 9
7:00 am	**Registration** 7:00 am - 5:00 pm	**Registration** 7:00 am - 4:00 pm	**Registration** 7:00 am - 2:00 pm
8:30 am	Plenary: Defense Conversion/ Technology Reinvestment — New Opportunities For Industry 8:30 -11:00 am	Workshop: How To Successfully Tap Into The Government's Technology Bank 8:30 - 11:00 am	Concurrent Workshops: International Technology Transfer Forum Technology Alliance Opportunities In The Pacific Basin Precision Casting Technologies For The Next Century 8:30 - 11:00 am
9:00 am			Exhibits Open 9:00 am - 3:00 pm
10:00 am	Exhibits Open 10:00 am - 6:00 pm	Exhibits Open 10:00 am - 5:00 pm	
1:00 pm	Concurrent Symposia: Advanced Manufacturing Computer Hardware Environmental Technology Materials Science Photonics 1:00 - 3:00 pm	Concurrent Symposia: Information Management Materials Science Power & Energy Robotics Virtual Reality/Simulation 1:00 - 3:00 pm	Concurrent Symposia: Advanced Manufacturing Biotechnology/Medical Technology Environmental Technology Materials Science Video/Imaging Technology 1:00 - 3:00 pm
3:30 pm	Concurrent Symposia: Artificial Intelligence Biotechnology/Medical Technology Computer-Aided Design & Engineering Test & Measurement Video/Imaging 3:30 - 5:30 pm	Concurrent Symposia: Advanced Manufacturing Artificial Intelligence Computer Software Environmental Technology Test & Measurement 3:30 - 5:30 pm	
	Technology Transfer Week Ceremonies & Reception Exhibits Hall 6:00 - 7:30 pm	Technology Transfer Awards Dinner Marriott Hotel 7:00 - 9:00 pm	

National Technology Transfer Week

December 5 - 11, 1993

Working To Keep America Strong

This December in the Anaheim Convention Center, three events coverge with a single goal: to help improve the U.S. economy and industrial competitiveness by transferring leading-edge technologies to new commercial markets. In addition to Technology 2003, Technology Transfer Week will feature:

Technology Transfer Society Annual Meeting "How To Make Money In Technology Transfer" December 6-7

The T[2] Society, the leading society for individuals and firms engaged in technology transfer, will offer a dynamic forum featuring a "how to" approach to licensing and brokering, a review of winning mechanisms and hot technologies, and a look at the latest government thrusts, such as the Technology Reinvestment Program, and technical assistance networks. Call (317) 262-5022 for more information.

"Capitalizing Geographic Information Technology" December 8

Sponsored by the American Society for Photogrammetry & Remote Sensing, this one-day symposium will spotlight emerging business and financial opportunities in remote sensing, Geographic Information System (GIS), and Global Positioning System (GPS) technologies, and will vignette specific industry R&D efforts in these rapidly-growing, economically-critical areas. For more information call (505) 277-3622.

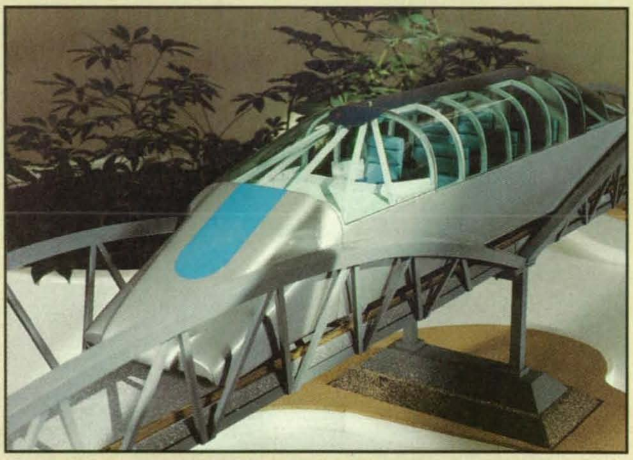
Your Technology 2003 symposia registration is your passport to all the events of Technology Transfer Week: complete and three-day symposia registrants may attend the sessions of these other conferences at no additional charge; one-day symposia registrants can attend sessions on the day(s) they are registered.

If your society or association is interested in holding a regional meeting as part of National Technology Transfer Week this year in Anaheim or next year in Washington, DC, contact Joseph Pramberger at (800) 944-NASA or (212) 490-3999.

Technology 2003 Exhibits: Your One-Stop Shopping Place For Innovative Ideas

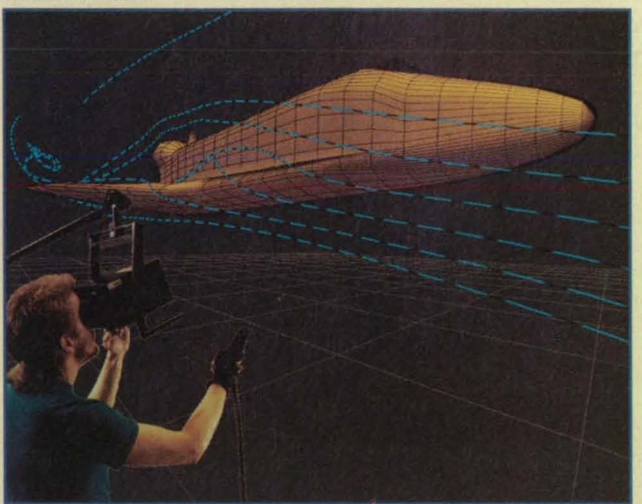
As you walk through the giant Technology 2003 exhibits hall, you'll see, touch, and test an amazing array of technologies, from electronics and computing devices to new materials and manufacturing techniques. Here's a partial list of the more than 250 federal laboratories, universities, and high-tech companies who will be demonstrating their latest inventions, products, and services:

Aerospatiale
Alberta Economic Development & Tourism
Allied Signal Kansas City
Altron Inc.
American Inventors Corp.
American Society for Photogrammetry & Remote Sensing
Ames Research Center
Arnold Engineering Development Center
Austrian Trade Commission
Ballistic Missile Defense Organization Technology Applications Program
BF Goodrich Aerospace
Brookhaven National Laboratory
Bulova Technologies Inc.
California Manufacturing Technology Center
Canon Communications Inc.
Catalyst Advertising/*International Invention Register*
Center for Optics Manufacturing
Centro Estero
Corning Inc.
COSMIC
Cybernet Systems Corp.
Datatape Inc.
Diamonex Inc.
Earth Data Analysis Center
Edgewood Research, Development, & Engineering Center
Electromechanical Systems Inc.



The Cybertran, a breakthrough concept in high-speed mass transit, will be displayed by Idaho National Engineering Lab. The computer-controlled, electrically-powered vehicle would travel in elevated guideways at speeds up to 150 mph between cities. It would cost just 10 to 20 percent of conventional rail systems and use only 30% of the energy of existing automobile and aircraft systems.

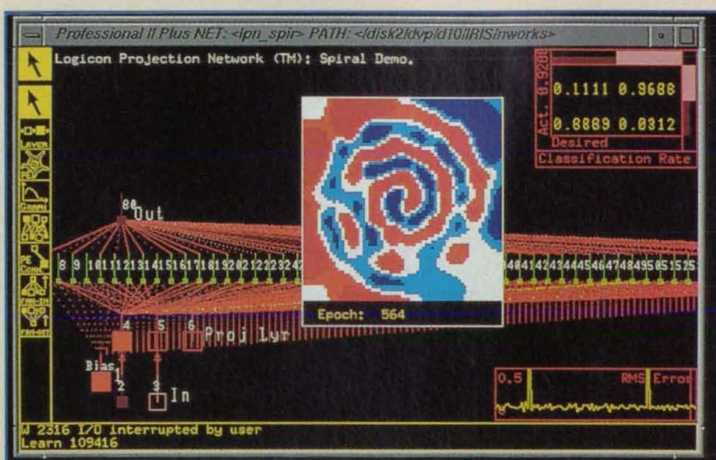
Ames Research Center will demonstrate its Virtual Wind Tunnel, which generates incredible 3D simulations of flows around aircraft.



ESL Inc., a subsidiary of TRW
Federal Aviation Administration
Federal Highway Administration
Federal Laboratory Consortium
Geophysical Survey Systems Inc.
Goddard Space Flight Center
Great Lakes Composites Consortium
HEMCO Corp.
Hewlett-Packard Co.
Hughes Microelectronics
Hypertat Corp.
Idaho National Engineering Laboratory
IIT Research Institute
IIT Research Institute, Manufacturing Technology Information Analysis Center
Indiana University Office of Technology Transfer
Infolytica Corp.
Information Handling Services
Inframetrics
INPEX
Irvine Sensors Corp.
Jet Propulsion Laboratory
JFW Industries
Johnson Space Center
Kennedy Space Center
Knowledge Express Data Systems
Langley Research Center
Lawrence Berkeley Laboratory
Lawrence Livermore National Laboratory

Learn how your company can capitalize on the expertise and services of the National Institute of Standards & Technology's Manufacturing Technology Centers (MTCs). The MTCs help firms identify, evaluate, install, and exploit advanced technology in their manufacturing and business operations.

Lewis Research Center
Lockheed Missiles & Space Co.
Machida Inc.
Macsyma
Marshall Space Flight Center
Mid-Atlantic Technology Applications Center
NASA
NASA Center for Aerospace Information
NASA Far West Regional Technology Transfer Center
NASA STI Program
NASA Tech Briefs
NASA Technology Transfer Network
National Center for Toxicological Research
National Institute of Standards & Technology
National Renewable Energy Laboratory
National Technology Transfer Center
Naval Research Laboratory
NAWCWPNS, China Lake
NERAC Inc.
NeuralWare Inc.
New Technology Week
Novecon Technologies
Novespace
Oak Ridge National Laboratory
Olympus Corp.
Pacific Coast Technologies
Pacific Northwest Laboratory
Princeton University Plasma Physics Laboratory
Proto Manufacturing
Racal-Dana Instruments Inc.
RAMOT—University Authority for Applied Research & Industrial Development
Research Systems Inc.
Research Triangle Institute
Resonetics Inc.
Rexham Industrial
R.G. Hansen & Associates
Rocketdyne Div. of Rockwell Intl.
Sandia National Laboratories
Simmonds Precision
Society for the Advancement of Material and Process Engineering (SAMPE)
Sonic Perceptions Inc.
Sonoscan Inc.
Spire Corp.
State/Industry-University Cooperative Research Center
Stennis Space Center
Technology Transfer Society
Technology Utilization Foundation
Thiokol
Tiodize Inc.
United Technologies Corp.
Universal Technology Corp.
University of Dayton Research Institute
University of Georgia
University of Texas Health Science Center at San Antonio
U.S. Air Force "AFSTAR" Display
U.S. Air Force Armstrong Laboratory
U.S. Air Force Manufacturing Technology Directorate (MANTECH)
U.S. Army Aeromedical Research Laboratory
U.S. Army Armament Research, Development, & Engineering Center
U.S. Army Research Laboratory
U.S. Dept. of Agriculture—Agricultural Research Service
U.S. Dept. of Agriculture—CSRS Office of Agricultural Materials
U.S. Dept. of Energy, Efficiency & Renewable Energy
U.S. Dept. of Energy Small Business Innovation Research
U.S. Dept. of Energy Technology Utilization Office
U.S. Dept. of Energy/Triodyne Inc.
U.S. Dept. of the Interior
U.S. Naval Academy
Veritec Inc.



NeuralWare will show its line of AI-based software including the NeuralWorks Professional II/PLUS, which features some of the most powerful recent advances in neural technology.

Is your company missing from this list?

Call Evelyn Mars at (800) 944-NASA to find out how you can exhibit at Technology 2003.

Technology 2003 Conference Program

Tuesday, December 7

Tues., 8:30 - 11:00 am

Plenary Session: Defense Conversion & Technology Reinvestment—New Opportunities For Industry

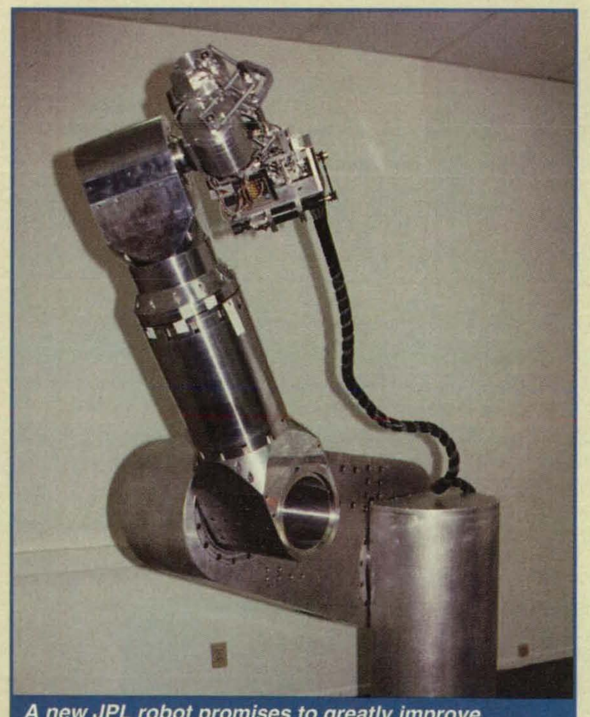
Invited speakers include:
Albert Gore, Vice President of the United States
Daniel Goldin, Administrator, National Aeronautics & Space Administration (NASA)
Lee Buchanan, Director, Defense Sciences Office, Advanced Research Projects Agency (ARPA)

Discover how you can benefit from the federal government's multi-billion dollar effort to convert aerospace/defense technologies to commercial markets and develop new "dual-use" technologies. Learn about opportunities for your company to participate in the Technology Reinvestment Project (TRP), a program of matching grants in various technological areas to explore commercial applications of government-funded R&D. And hear from TRP winners and what their work can mean to your bottom line.

Tues., 1:00 - 3:00 pm

National Critical Technologies Concurrent Symposia

Five concurrent sessions will be held during two-hour time blocks Tues.-Thurs. Presentations will last 30 minutes, including a question and answer period. Symposia registrants may attend whole sessions (four presentations) or individual presentations from a number of different sessions. Meeting rooms will be situated in close proximity for easy movement during sessions. Room assignments will be listed in the final program distributed at the show.



A new JPL robot promises to greatly improve manufacturing operations.

Advanced Manufacturing Part 1

Eight-Degree-Of-Freedom Force-Controlled Macro-Micro Robot

Dr. Neville Marzwell, Manager, Advanced Technology Programs, Jet Propulsion Lab; Yulun Wang and Amante Mangaser, Computer Motion Inc.

A robot capable of high accuracy and precise force control has been developed for microsurgery and manufacturing operations such as polishing, finishing, cleaning, grinding, and deburring. It offers a low-cost, efficient alternative to current methods, which require manual labor or delicate machinery.

Cooperative Computer Vision for Flexible Advanced Robot Controllers

Dr. Neville Marzwell, Jet Propulsion Lab; Tom Peurach and Brian Mitchell, Cybernet Systems Corp.

Current robotic systems provide limited support for CAD-based, model-driven visualization, sensing algorithm development and integration, and automated graphical planning systems. This presentation will describe an ongoing effort to apply advanced robotics to automated manufacturing and assembly operations. The resulting tool will enable sensing and planning from computationally-simple graphical objects.

PAWS: Control of Welding Through Software and Hardware

Thomas Doyle, Babcock & Wilcox, R&D Division

Integrating off-line planning and real-time control, the Navy's Programmable Automated Welding System (PAWS) provides an automated means of planning, controlling, and evaluating critical welding situations to improve productivity and quality. PAWS can acquire input from many welding process sensors and fuse this information to produce high-quality welds with limited operator intervention.

Optical and Ultrasonic Sensing of Gas Metal Arc Welding

H.B. Smartt, J.A. Johnson, N.M. Carlson, P.L. Taylor, A.D. Watkins, and E.D. Larsen, Idaho National Engineering Lab; A.V. Clark, Jr., S.R. Schaps, and C.M. Fortunko, National Institute of Standards & Technology

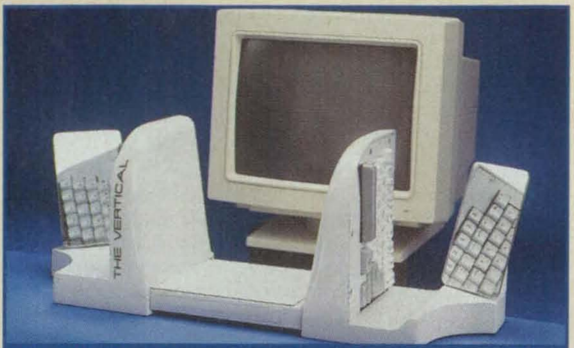
The presenters will describe two prototype sensors developed for the PAWS Program that offer a heretofore unavailable combination of in-process sensing capabilities for arc welding. A video-based sensor provides data on the size and location of the weld pool, the centerline cooling rate of the weld bead behind the pool, and the standoff distance of the torch, while a noncontacting ultrasonic sensor determines in-process weld quality.

Computer Hardware

Spacecraft Onboard Information Extraction Computer (SOBIEC)

David Eisenman, Deputy Manager, Flight Command & Data Management Systems, Jet Propulsion Lab; Raphael Some, Technical Director-Computer Systems, Irvine Sensors Corp.; Dr. Stephen Colley, Chairman and Founder, nCUBE

This presentation will spotlight an extremely low power/weight/volume computer node that couples 3D IC stacking with state-of-the-art processor IC technology. SOBIEC integrates a 32/64 bit microprocessor, up to 16 MB of memory, and 14 bi-directional I/O channels into a package equivalent in size, weight, and power dissipation to that of a single-chip processor. Developed for use in spaceborne massively parallel computers, SOBIEC offers applications in avionics, embedded computers, portable computing, workstation accelerators, and general-purpose processing.



The "Vertical" keyboard reduces the risk of repetitive motion injuries.

Pen-Based Computers: Computers Without Keys
Cheryl Conklin, Systems Design Engineer, Analex Space Systems
Pen-based computers, which allow data to be entered simply by writing on the screen surface with a stylus, increase the accuracy and completeness of data, eliminate duplication of work, and augment the timeliness of information captured. Commercial potential: inventory management, sales automation, insurance, health care, and virtually any other industry.

"The Vertical"
Stephen Albert and Jeffrey Spencer, Co-inventors, Ergonomic Interface Keyboard Systems
A novel keyboard design offers a potential solution to a worldwide health problem: repetitive motion injuries (RMI), such as Carpal Tunnel Syndrome, suffered by computer users. The invention's easy-to-use vertically-arranged keyboard halves reduce the risk of RMI by requiring users to position their bodies in optimal alignment with the keyboard.

A Systems Approach to Computer-Based Technical Training
Gaylen Drapé, Project Manager, ENSCO Inc.
An advanced computer-based training system developed through NASA's SBIR program utilizes digital data compression technology to run audiovisual applications over a local area network. Potential spinoff products include custom courseware for technical skills training, courseware development software tools, and training systems engineering services.

Environmental Technology Part 1

Seed Viability Detection Using Computerized False-Color Radiographic Image Enhancement
J.A. Vozzo, Research Plant Psychologist, U.S. Department of Agriculture, and M. Marko, Research Psychologist, N.Y. State Department of Health
The seeds of economically-important indigenous tree species are difficult and expensive to collect, store, and germinate. Furthermore, germination rates may be as low as 50 percent. A new technique uses false-color radiographic image enhancement to predict seed viability.

A Commercialized, Continuous Flow Fiber-Optic Sensor for Trichloroethylene and Haloforms
Mark Johnson, Senior Chemist, and James Wells, Sensor Program Manager, Purus Inc.
Purus has commercialized a fiber-optic chemical sensor developed by Lawrence Livermore National Lab for detection of low µg/L levels of trichloroethylene and haloforms — chlorinated hydrocarbons that pose health and environmental dangers when used extensively. The sensor offers a quick, low-cost, and highly-accurate alternative to current sampling and analysis methods, and can be used as an industrial process monitor or as a laboratory screening instrument.

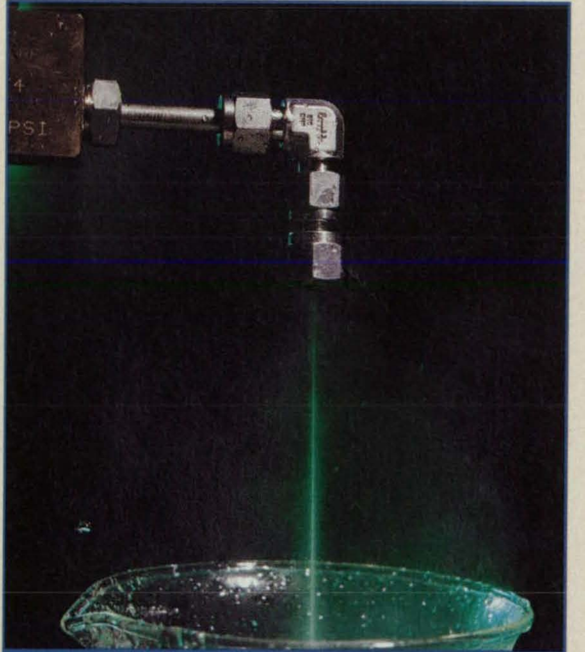
New Automated Bioassay for Detecting Aqueous Pollutants and Pharmaceuticals
David Noever, Research Scientist, Marshall Space Flight Center
Mr. Noever will discuss using motile single cells of Tetrahymena as a low-cost bioassay for chemical toxicity. Monitoring changes in the cells' swimming speed and direction has shown equal or better detection reliability than existing whole animal or bacterial assays.

A Modular Approach for Automated Sample Preparation and Chemical Analysis
Michael Clark, EG&G Idaho
A collaboration of DOE, industry, and university labs is developing automated chemical analysis technology to support environmental remediation. A proposed system incorporates interchangeable automated software modules—each performing a specific task such as measuring, filtering, analysis, or data interpretation—that are monitored by a central command computer.

Materials Science Part 1

Bench-Scale Synthesis of Nanoscale Materials
M.F. Buehler, D.W. Matson, J.C. Linehan, and J.G. Darab, Research Engineers/Scientists, Pacific Northwest Lab
Industrial demand for large quantities of nanoscale powders has sparked a surge of new processing techniques to produce ultrafine materials at high rates. Current techniques all are limited by low production rates or the inability to synthesize uniformly-sized powders. This presentation will describe a new bench-scale, hydrothermal process that overcomes these obstacles and continuously produces nanometer-size powders at a rate of pounds per day.

Synthesis and Characterization of Advanced Materials Using the Sol-gel Process
Dr. Josephine Covino, Head, Applied Mechanics Branch, Naval Air Warfare Center Weapons Division
This presentation will address the synthesis of ceramics and ceramic coatings using the sol-gel process, which involves a controlled hydrolysis of metal alkoxides or metal organics followed by a controlled dehydration. Dr. Covino will discuss a variety of applications including coatings for electrocromic devices, laser gyro bodies, hermetic coatings for optical fibers, coatings for lightweight structural applications, ceramic foams for thermal insulation, use of organic and inorganic dyes in silica-based ceramics, and ceramics for radomes.



A Department of Energy technique produces nanoscale materials at extremely high rates.

Deposition of Tantalum Carbide Coatings on Graphite by Laser Interactions
Dr. James Veligdan, Reactor Systems Division, Brookhaven National Lab
Dr. Veligdan will illustrate a laser-assisted chemical vapor reaction process that produces defect-free hydrogen-resistant coatings for carbons, graphite, and composite materials. This technology could significantly reduce the cost of producing refractory carbides on carbon-based substrates.

Development of a Unique Polyurethane Primer/Topcoat
H.L. Novak, Scientist, USBI Co.
BOOSTERCOAT©, a nonleaded/nonchromated polyurethane single coat, offers excellent corrosion protection, flexibility, adhesion, and chemical and solvent resistance. The environmentally-acceptable coating is suited for harsh environments and can be applied to machinery, transportation equipment and vehicles, and structures made of aluminum alloys and pretreated steel panels.

Photonics

Optical Processing/Scanning Defect Mapping for Semiconductor Device Fabrication
Bhushan Sopori, Senior Project Coordinator, National Renewable Energy Lab
This presentation will center on two innovations: an optical processing furnace for commercial wafer processing based on the recent discovery that illumination of a semiconductor-metal interface with a suitable spectrum can produce a melt at the interface; and a high-speed laser scanning system that produces maps of the spatial distributions of crystal defects such as grain boundaries and dislocations in semiconductor wafers.

Neutral Ion Sources in Precision Manufacturing
Steven Fawcett, Optical Fabrication Branch, Marshall Space Flight Center
Mr. Fawcett will discuss ion figuring of optical components, which can alleviate some of the problems associated with traditional contact polishing. Because the technique is noncontacting, edge distortions and rib structure print-through do not occur.

High-Power Diode Lasers for Solid-State Laser Pumps
Kurt Linden, Director of Commercial Products and Services, Spire Corp.
High-power 780-830 nm diode lasers have been developed to pump solid-state lasers, which have higher optical properties than diode lasers. The resulting small and portable YAG, YLF, and related laser systems are suitable for metal-working, cutting, industrial measurement and control, ranging, and wind-shear/atmospheric turbulence detection, and for medical applications such as microsurgery, ophthalmology, and dentistry.

Pulsed Diode Ring Laser Gyro (PDRLG) Development
Joseph De Fato, Engineer, Naval Command, Control & Ocean Surveillance Center
The PDRLG reduces frequency locking by employing two pulsed semiconductor laser diodes modelocked in a ring cavity. The device permits implementation of an inexpensive "gyroscope on a chip" while providing inertial sensitivity adequate for a broad range of military, commercial marine, and land navigation system applications.

Tues., 3:30 - 5:30 pm

National Critical Technologies Concurrent Symposia

Artificial Intelligence Part 1

Refining Fuzzy Logic Controllers with Machine Learning
Hamid Berenji, Senior Research Scientist, Sterling Software
Scientists at NASA's Ames Research Center have developed a method to automatically fine-tune fuzzy logic controllers. The GARIC (Generalized Approximate Reasoning-Based Intelligent Control) architecture learns from past performance and modifies the labels in the fuzzy rules to improve performance. This technology can simplify and automate the application of fuzzy logic control to a variety of systems including such consumer products as appliances, cameras, and cars.

Fuzzy Classifier System for Process Control
C.L. Karr and C. Phillips, U.S. Bureau of Mines
A new fuzzy-logic-based adaptive control system learns to efficiently manipulate complex control variables without the benefit of *a priori* knowledge about the problem environment's response characteristics. The simple, versatile controller offers practical payoffs in diverse industrial fields including mineral processing, chemical engineering, and waste disposal.

Fuzzy-Neural Control of an Aircraft Tracking Camera Platform
Dennis McGrath, Naval Air Warfare Center-Aircraft Division
A hybrid fuzzy-neural system developed by Navy engineers offers the ability to fine-tune encoded knowledge and thereby make machine intelligence function much more like natural intelligence. This technique could be applied to many commercial nonlinear control systems, such as process control and industrial robot control.

H46 Rotor Blade Balance Using Artificial Neural Networks
Marco Tedeschi, Aerospace Engineer, Naval Air Warfare Center-Lakehurst Aircraft Division
Mr. Tedeschi will discuss the Navy's use of neural network technology in automatically adjusting aircraft rotor blades to minimize vibration levels for all flight profiles. Both military and commercial markets could benefit because it eliminates unnecessary maintenance man- and flight-hours, which translates into considerable cost savings.

Biotechnology/Medical Technology Part 1

Microencapsulation of Anti-Tumor, Antibiotic, and Thrombolytic Drugs in Microgravity
Dennis Morrison, Senior Biotech Scientist, Johnson Space Center
Mr. Morrison will describe semipermeable microcapsules that deliver antibiotics or thrombolytic enzymes directly to organs. An aqueous-soluble, anti-tumor drug and an oily, radio-contrast medium are co-encapsulated in this unique drug delivery system that can be visualized by a CT scanner to insure delivery of the cytotoxic drug to the target tumor.

Cubanes: Super Explosives and Potential Pharmaceutical
A. Bashir-Hashemi, Research Chemist, Geo-Centers
The cubane molecule, in which eight carbon atoms are locked in a cubic framework, shows great potential for both military and pharmaceutical applications. Octanitrocubane, with a predicted density of 2.1 g/cc and strain energy of more than 165 kcal/mole, is considered to be the "super-explosive," while cubane derivatives submitted to the National Institutes of Health for preliminary biological activity screening have displayed promising anti-cancer and anti-HIV activity.

Dual Use of Image-Based Tracking Techniques: Laser Eye Surgery and Low Vision Prosthesis
Richard Juday, Manager, Image-Based Tracking, Johnson Space Center
Mr. Juday will describe potential medical application of JSC's image-based tracking technology. These include noncontact, retinal position stabilization during laser photocoagulation surgery, and image warping as a prosthesis for certain forms of human low vision.

Medical Imaging Using Cooled Optically-Stimulated Luminescence
Steven Miller, Staff Scientist, Battelle, Pacific Northwest Labs
An advanced laser-addressable ionizing radiation storage phosphors technology has demonstrated significant potential for medical

imaging. The phosphors can be molded into flat sheets using a variety of commercially-available plastics to provide an image plate with several advantages over x-ray film.

Computer-Aided Design & Engineering

The Reliability, Availability, and Maintainability in Computer-Aided Design (RAMCAD) Program

Mary Klement, Director of Logistics Engineering, Hughes Missile System Company

Hughes' RAMCAD design evaluation tool integrates reliability, maintainability, and supportability analysis functions into electronic, mechanical, and structural design workstations. A common user interface enables designers to predict electrical Mean Time Between Failures (MTBF), Mean Time To Repair (MTTR), mechanical failure rate, and structural useful life, and to conduct optimum repair level analyses on a design concept.

Analytical Design Package

Michael Gran, Aerospace Engineer, U.S. Air Force

The Air Force is developing an integrated design tool for frameless transparencies, aircraft interfaces, and their respective tooling. The package will comprise CAE software, structural and geometric modeling, finite element dynamic structural analysis, thermal analysis, optics analysis, a materials database, and molding simulation software.

Assembly Flow Simulation of a Radar Design

Wesley Rutherford and Peter Biggs, Allied Signal Aerospace

SLAM II, a software simulation package that predicts the assembly flow time of a new radar design, can reduce the assembly and testing cycle time from 26 to six weeks. The model selects the radar, production facility, and equipment to provide the most manufacturable assembly possible.

CONFIG: Integrated Engineering of Systems and Their Operation

Jane Malin, Research Psychologist, Johnson Space Center; Dan Ryan, Technical Staff, MITRE; Land Fleming, Computer Systems Analyst, Lockheed Corp.

The CONFIG prototype demonstrates advanced integrated modeling, simulation, and analysis to support concurrent CAE. The program permits qualitative and symbolic modeling for early conceptual design and can help evaluate system operability and fault tolerance.

Test & Measurement Part 1

Continuous Measurement of Aircraft Wing Icing

Stephen Yao, Senior Research Engineer, Axiomatics Corp.

The safety risk posed by ice formation on the wings of aircraft can be reduced using small, lightweight, and inexpensive dielectric sensors. These sensors, which use a central electrode driven by a sine wave to continually monitor the presence and thickness of ice, can improve the efficiency of deicing procedures on the ground.

An Acousto-Optic Tunable-Filter-Based Near-Infrared Spectrometer for Analysis of Gasolines and Diesel Fuels (Presentation Part 1)

Steve Westbrook, Group Leader, Belvoir Fuels and Lubricants Research Facility

A near-infrared spectrophotometric analyzer measures gasoline and diesel fuel properties such as octane number, benzene content, aromatics content, and oxygenate content. The extremely rugged and portable analyzer is suited for laboratory and field applications.

Analysis of Middle Distillate Fuels By FTIR (Presentation Part 2)

Dr. George Fodor, Staff Scientist, Belvoir Fuels and Lubricants Research Facility

A new analytical method based on Fourier transform infrared (FTIR) spectroscopy permits rapid and reliable measurement of several pertinent fuel properties simultaneously. Based on the measurement of characteristic fundamental resonance frequencies in the infrared region (4000 to 650 cm-1), the method could be applied to screening-type specification conformance testing at refineries, fuel distribution depots, and service stations.

Electromagnetic Probe Technique for Fluid Flow Measurements

G.D. Arndt, Chief, Electromagnetic Systems Branch, Johnson Space Center; J.R. Carl, Project Specialist, Lockheed Engineering and Science Company

A microwave system measures instantaneous changes in flow conditions of two fluids or two states of a single fluid in a flowline or holding container. Differences in the dielectric constants of the fluids are used to measure the phase of the complex reflection coefficient as seen by a probe. The system is designed for oil/gas field pipeline measurements and reservoir or storage tank monitoring.

Ultrasonic Real-Time Determination of Chromium Thickness During Plating of Tubes

Julius Frankel, Physicist, Augustino Abbate and Mark Doxbeck, Mechanical Engineers, Benet Labs

A computer-controlled ultrasonic system provides real-time measurements of chromium thickness as it is being plated onto steel tubes. Applicable to any commercial electroplating process, the system has the potential to reduce plating time while improving process and product control.

Video & Imaging Technology Part 1

A Multimedia Adult Literacy Package

Dr. Jerry Willis, Adult Literacy Tutor Project, University of Houston; James Villareal, Johnson Space Center

The Adult Literacy Tutor is simulation-based instructional software for adults lacking functional reading skills. The package combines fuzzy logic, NASA's Intelligent Computer-Assisted Training (ICAT) system, and emerging hypermedia sound, graphics, and video technologies to place the adult in interactive simulations of real-life activities.

Mapping, Analysis, and Planning System

C. Ross Hinkle, Carlton Hall, and Mark Provancha, Bionetics Corp.; William Knott and Burton Summerfield, Kennedy Space Center

An environmental management, impact assessment, and monitoring system for local workstations contains a central multimedia database of more than ten years of data on vegetation communities, wetlands, and endangered species habitats. Site- and project-specific databases provide information on permit requirements, regulations, and environmental considerations through digital imagery, video, audio, and hypertext.

Remote Sensing for Urban Planning and Disaster Assessment

Bruce Davis, Chief Scientist, and Nicholas Schmidt, Scientist, Stennis Space Center

The presenters will illustrate two applications of remote sensing using NASA's Calibrated Airborne Multispectral Scanner: urban change analysis as demonstrated through a utility company application identifying and predicting future use of underdeveloped land, and assessment of post-disaster damage levels, as demonstrated in South Florida following Hurricane Andrew.

Remote Sensing and the MS High-Accuracy Reference Network

Mark Mick, Program Manager, and Stan Wooley, Project Manager, Stennis Space Center

The High-Accuracy Reference Network (HARN), a group of reference stations used for geodetic control of field, airborne, and space-borne monitoring activities throughout Mississippi, has been combined with NASA remote sensing technology to accumulate geographic information. Potential benefits include accurate, repeatable, and cost-effective surveys.

Tues., 6:00 - 7:30 pm

Technology Transfer Week Ceremonies and Reception

Speaker: Peter Wilson, Governor, State of California (invited)

Wine and cheese reception in the exhibits hall offers the chance to network with exhibitors and attendees in an informal atmosphere. (Open to all registrants.)

Wednesday, December 8

Wed., 8:30 - 11:00 am

Plenary Workshop: How to Successfully Tap Into the Government's Technology Bank

(Speakers TBA)

Experts from NASA, the departments of Defense and Energy, and other major federal agencies will explain the basics you need to know to license government patents, enter into Cooperative Research and Development Agreements (CRADAs) with federal labs, and obtain Small Business Innovation Research (SBIR) grants. Find out how to get started, whom to contact, and what resources are available now.

Wed., 1:00 - 3:00 pm

National Critical Technologies Concurrent Symposia

Information Management

High-Speed Data Search

James Driscoll, University of Central Florida, Department of Computer Science

A high-speed text retrieval system developed at NASA's Kennedy Space Center offers features not found in most commercial systems: statistical ranking of retrieved documents; the capability for natural language input; relevance feedback, in which user judgements about viewed information are used to automatically modify the search for further information; and semantics, an artificial intelligence concept wherein "surface level" knowledge found in text is used to improve the ranking of retrieved data.

Database Tomography: Applications to Technical Intelligence

Dr. Ronald Kostoff, Director of Technical Assessment, Office of Naval Research; Henry Eberhart, Weapons Planner, Naval Air Warfare Center

This presentation will focus on a revolutionary approach for extracting information from large textual databases. The method, which uses the full database text instead of just key or index words, provides structures and relationships from seemingly disparate data.

Automated Mainframe Data Collection in a Network Environment

David Gross, Computer Engineer, Analex Space Systems

The Kennedy Space Center's Centralized Automated Data Retrieval System (CADRS) provides a simple and highly automated interface to numerous dissimilar data systems, with the capability to handle system queries, data transfers (both network and asynchronous), and data conversions. The methods developed for CADRS have strong commercial potential for any industry that needs interdepartment, inter-company, or inter-agency data communications.

Advanced Automatic Parts Identification (API) System

Donald Roxby, Space Systems Div., Rockwell International Corp.

Rockwell and NASA's Marshall Space Flight Center have teamed to develop a novel API system featuring a variable-size, machine-readable checkerboard symbol that can be applied directly onto most metallic and nonmetallic materials using safe, permanent marking methods. Known commercially as Vericode, the system overcomes the major deficiencies inherent in the basic bar code design—long code length, fixed size, close read distance, precise read orientation, marking difficulties/errors, and susceptibility to damage.

Materials Science Part 2

High-Elongation Elastomers

Vicki Brady and Russ Reed, Physical Scientists, Department of Defense

Navy researchers have developed unique liquid curable elastomers that exhibit high elongation and unusual toughness. They have utility as solventless coatings where dynamic properties, such as shrinkage and expansion, are an issue, and could be cast into complex shapes, leading to other applications including highly resilient parts with intricate configurations.

Solventless, Curable, Fluid Oligomeric Systems

Gene Lefave, President, and Leo Stanton, Technical Operations, Fluid Polymers Inc.; James Foreman, Research Chemist, Martin Marietta Electronics, Information, & Missiles Group

A family of hybridized liquid polymers has been developed for high-performance microwave, acoustical, and mechanical applications. They exhibit unusual electrical and mechanical properties, permitting the development of products with newly engineered features that are impossible to produce with other materials.

Plasma Treatment of Polymer Dielectric Films to Improve Capacitive Energy Storage

A. Yializis, President, Sigma Labs, and M. Binder, Army Research Lab

The increasing requirement for device miniaturization and portable equipment is fueling a demand for dielectric materials with improved electrostatic energy storage capabilities. The presenters will detail efforts to increase, by plasma treatment, the breakdown strength of polyvinylidene (PVDF) film—the only high dielectric constant polymer film available for high-energy capacitor applications. Their research has shown that the breakdown voltage of a 12 µm PVDF film can be increased by up to 20%, representing a 44% increase in the energy storage of a PVDF film capacitor.

Development of Radiation-Resistant Cable Insulators

Dr. Bom Soon Lee, Metallurgist/Principal Investigator, Brookhaven National Lab

Dr. Lee will describe the creation of longer-lasting, radiation-resistant polyethylene cable insulators for use in nuclear power plants, high-energy accelerators, and spacecraft.

Power & Energy

Use of Magnetic Compression to Support Turbine Engine Rotor

Chris Pomfret, Project Engineer, Wright-Patterson Air Force Base

Mr. Pomfret will discuss a method of exploiting magnetic compression to counteract an engine's centrifugal forces by direct opposition rather than restraint. The proposed disk design offers a means of conserving weight and overcoming the structural limitations of materials.

Low-Power CMOS Digital Cell Library

Robert Schober, Jet Propulsion Lab

A CMOS digital cell library developed at JPL reduces power requirements by a factor of 10-100, down to 1.2 volts for the lowest power applications. The library can be scaled down to sub-micron geometries.

Solar Absorption Cooling: Renewable Energy Technology for Protecting the Ozone Layer and Demand Side Management

Russell Hewett, Task Leader, National Renewable Energy Lab

Mr. Hewett will describe the potential of solar absorption cooling technology to satisfy demands for air conditioning in office and commercial buildings that eliminates ozone-depleting refrigerants and improves air quality, and to help electrical utilities manage peak demands for power and minimize requirements for peaking electric generating equipment.

Fiber-Optic Solar Simulator (FOSS)

Bhushan Sopori, Senior Project Coordinator, National Renewable Energy Lab

FOSS produces an output beam that accurately simulates the solar spectrum by "mixing" three suitably filtered light beams in a randomized, tri-furcated fiber optical cable. The tabletop system measures the performance of solar cells, including multijunctioned cells, in approximately five minutes.

Robotics

Application of Dexterous Space Robotics Technology to Myoelectric Prostheses

Charles Price, Chief, Robotics Systems Technology Branch, and Cliff Hess, Lead Engineer, Dexterous Robotics, Johnson Space Center

JSC is developing highly dexterous robotic hands and arms for use in astronaut work environments. An example is the Extravehicular Activity Helper Retriever, a highly autonomous robot capable of seeking and retrieving objects of arbitrary shape adrift in a weightless orbital environment. The presenters will explain how technologies developed for this and other dexterous robots could be reapplied to improve myoelectrical prostheses.

U.S. Navy Omni-Directional Vehicle Development

Hillery McGowen, Physicist, Naval Surface Warfare Center

A Navy omni-directional vehicle has a drive system applicable to autonomous, remotely, or manually operated vehicles. Commercial applications include multi-directional forklifts, automatic guided vehicles in manufacturing environments, and remotely-controlled platforms used in nuclear facilities or hazardous waste cleanup.

Applying Robotics to HAZMAT

Richard Welch, Task Manager, Jet Propulsion Lab

HAZBOT III, a teleoperated mobile robot developed at JPL, will enable HAZMAT teams to locate, identify, and mitigate hazardous materials incidences without risking personnel. It features a tracked base with articulated front and rear sections that allow the vehicle to climb stairs and maneuver in tight surroundings, a six-degree-of-freedom manipulator that can unlock and open doors, and a gas detector for hazardous material identification.

Advanced Teleoperation: Technology Innovations and Applications

Paul Schenker, Group Supervisor, and Antal Bejczy, Technical Manager, Jet Propulsion Lab

The presenters will highlight JPL's teleoperation technology and its applications, including real-time 3D calibrated graphics displays, task visualization and planning systems, and shared manual-automatic controllers for high-degree-of-freedom robots utilizing multimode sensory input. Potential robotic microsurgery applications will be discussed.

Virtual Reality/Simulation

Anatomy Meets Virtual Reality: The Virtual Visual Environment Display (VIVED)

Laurie Sprague, LinCom, and Mike Goza, Johnson Space Center

A new virtual reality technology aids medical students in understanding the three-dimensional nature of human anatomical structures. VIVED one day could enable surgical students to learn how to perform high-risk procedures on virtual patients, and students of all ages to better understand anatomy by "touring" a simulated human body.

Low-Cost Virtual Reality Tool for Construction Equipment Design

Harry Frisch, Goddard Space Flight Center, and Harry Yae, University of Iowa

Technology developed for operator-in-the-loop simulation in space teleoperation has been applied to Caterpillar's backhoe and off-highway truck simulation. On an SGI workstation, the simulation integrates computer modeling of kinematics and dynamics, real-time computation and visualization, and an interface through the operator's console to create an innovative engineering design environment.

High-Performance Real-Time Flight Simulator

Jeff Cleveland, Project Engineer, Langley Research Center

Langley has implemented supercomputers for simulation mathematical model computation to support real-time man-in-the-loop flight simulation. Potential commercial uses include nuclear process control, power grid analysis, process monitoring, real-time simulation, and radar data acquisition.

ARTT: An advanced simulation tool for training

Application of Above Real-Time Training (ARTT) for Simulators: Acquiring High-Performance Skills

Dutch Guckenberger, Senior Software Design Engineer & Research Associate, ECC International Corp.

Mr. Guckenberger will describe Above Real-Time Training (ARTT), a simulated environment that functions at faster than normal time. Used to prepare personnel for real-world problems, this over-training method has potential military, commercial, and public education applications.

Wed., 3:30 - 5:30 pm

National Critical Technologies Concurrent Symposia

Advanced Manufacturing Part 2

Electron Beam/Optical Lithography Process for the Fabrication of Sub-Half-Micron-Gate-Length MIMIC Chips

James Sewell and Christopher Bozada, Electron Beam Lithography Team Leaders, Wright Patterson Air Force Base

A new hybrid method for manufacturing millimeter wave-microwave ICs offers the advantages of high-resolution E-beam lithography and the high throughput of optical lithography while essentially eliminating an entire lithography/metallization/liftoff process sequence. The technique has proven to be reliable for both trapezoidal and mushroom transistor gates and has been successfully applied to MESFET and HEMT wafers containing devices with gate lengths down to 0.10 micron and 75 x 75 micron gate pads.

Dry and Liquid Cold Fusion of Materials

Dr. Adrian Joseph, Research Director, Metafuse Corp.

Interstitial bonding/fusion of materials and alloys into surfaces of conductors normally requires high levels of energy, vacuum, and/or heat, as well as sophisticated equipment and skilled operators. A new process utilizing material resistances, variable DC pulsed frequencies uses minimal energy, leaves the substrate at ambient temperature, and requires no significant operator training. It can be done either in a dry solid or wet liquid form by both brush and bath technique.

Near-Net-Shape Manufacturing: Spray-Formed Metal Matrix Composites and Tooling

Kevin McHugh, Senior Scientist, and James Key, Techical Leader, Idaho National Engineering Lab

INEL researchers have developed spray forming technology for producing near-net-shape solids and coatings of a variety of metals, polymers, and composites. The technique, which combines novel spray nozzle design with advanced process control and on-line diagnostics of spray plume, offers unique opportunities for simplifying materials processing while improving product quality.

Hot Drape Forming of Composite Structural Shapes
R. Thomas Ott, Composites Engineer, Boeing Company
To fabricate composite parts for space station Freedom, Boeing engineers are employing a drape forming process that replaces labor-intensive, ply-by-ply lay-up. The process, used to produce structural shapes such as I-beams, C-channels, and angles, reduces labor costs by 50 percent while improving part quality.

Artificial Intelligence Part 2

Advances in Neural Network Pattern Recognition
Dr. Harold Szu, Leader, Neural Network and Automation Group, Naval Surface Warfare Center
Dr. Szu will demonstrate applications for two advances in pattern recognition: improved performance measures for minimizing misclassification error and optimizing receiver operating characteristics; and wavelet features whose shift and dilation parameters and waveforms are automatically computed by a neural network for a particular application. Originally developed for noncooperative target identification, these techniques are expected to perform well in industrial inspection, medical imaging, and character and speech recognition.

New Approaches for Real-Time Decision Support Systems
Dr. Charles Hair, RDT&E Division, Naval Command, Control, & Ocean Surveillance Center
Navy research into ways of improving decision support systems for tactical command and control situations has yielded two new computer tools that could benefit any application where decisions must be made under time pressure, based on incomplete or ambiguous data. Dr. Hair will illustrate potential uses in medicine and weather forecasting.

Knowledge-Based Commodity Distribution Planning
Dr. Victor Saks and Ivan Johnson, Carnegie Group Inc.
The Knowledge-Based Logistics Planning Shell (KBLPS) is a state-of-the-art Decision Support System with a rich interactive graphics user interface and powerful planning algorithms. The authors will explain how KBLPS, developed to support Army logisticians, can be applied to commodity distribution planning in the commercial arena.

Intelligent Hypertext System Provides Rapid, Effective Access to Information in Large Documents
Nathalie Mathe, Artificial Intelligence Research Branch, Ames Research Center
The CID (Computer Integrated Documentation) hypertext system features the unique ability to automatically acquire and reuse the context in which previous searches were appropriate. The design of contextual links to retrieve information is based not only on the way the documentation has been built, but also on user information requirements and feedback; thus the user continually augments and refines the intelligence of the retrieval system.

Computer Software

Automatic Translation Among Spoken Languages
Sharon Walter, Computer Engineer, Rome Laboratory
The Machine-Aided Voice Translation System employs speech recognition, machine translation, and speech generation technologies to translate spoken English into spoken Spanish and vice versa. Project extensions will expand English/Spanish capacity and add translation capabilities for other languages.

A PC Program to Optimize System Configuration for Desired Reliability at Minimum Cost
Steven Hills, Engineering Specialist, EG&G Idaho
The System Reliability Optimizer uses an algorithm to derive true optimum system configuration while considering multiple redundancy of both standard and optional components. The algorithm applies a pair-wise comparative progression technique that allows it to derive optimum design in a few seconds from only a small fraction of the total number of possible combinations of components and options.

Evolving Software Reengineering Technology for the Emerging Innovative-Competitive Era
Philip Hwang, Chief Scientist and Engineer, Naval Surface Warfare Center
New software reengineering technology for modernizing existing legacy software aims to reduce maintenance costs, improve software quality, and shorten the time required to produce the modernized software. Mr. Hwang will discuss how reengineering technology is integrated with software development technology, such as in software reuse and automatic program generation.

A Library of Reusable Software Components with Automatic Parallelism
Michael Boucher, Principal Analyst, Dakota Scientific Software Inc.
NASA's Computer Software Management and Information Center has available an extensive body of computer software, much of which is useful but designed for computers that are either outdated or extremely specialized. Mr. Boucher will describe a new method of transforming and updating these "dusty deck" codes for use on a variety of hardware and software platforms, including high-performance computers.

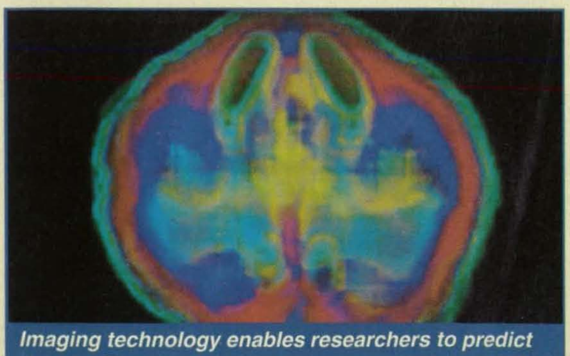
Environmental Technology Part 2

Photovoltaic Power Without Batteries for Continuous Cathodic Protection
Wallace Muehl, Electrical/Mechanical Engineer, U.S. Navy
Navy engineers have developed a Photovoltaic-Powered Impressed Current Cathodic Protection System that provides continuous corrosion protection for ships, bridges, pipelines, and other structures. It uses only renewable energy and requires no auxiliary/battery backup system.

CFC Replacement Alternatives
H. Richard Ross, Group Leader, Sverdrup Technology Inc.
Mr. Ross will discuss efforts to find a replacement fluid for trichlorotrifluoroethane (CFC-113), utilized in precision cleaning operations by the aerospace, semiconductor, microelectronics, and medical industries. Experiments suggest that some azeotropic mixtures of isopropyl alcohol and glycol ethers would provide viable options.

Supersonic Gas-Liquid Cleaning Systems
Raoul Caimi and Eric Thaxton, Kennedy Space Center
KSC is developing a system to replace solvent flush methods using CFC-113 for internal and external cleaning and cleanliness verification of all fluid system components. The proposed system uses gas-liquid supersonic nozzles to generate high impingement velocities at the surface of the object to be cleaned.

Regenerating Used Aqueous Cleaners with Ozone and Electrolysis
Mike McGinness, President, Custom Process Systems and Service Co.
A novel process converts used aqueous cleaning solutions back into a usable cleaning product. The used solution is treated with an



Imaging technology enables researchers to predict the viability of seeds from economically-important tree species (page G).

advanced oxidation process, which converts insoluble fats and oils into useful soluble surfactants. This reduces the amount of water and chemicals used in the cleaning process while conserving energy and waste disposal costs.

Test & Measurement Part 2

Microwave Sensor for Ice Detection
G.D. Arndt and A. Chu, Johnson Space Center; L.G. Stolarczyk and G.L. Stolarczyk, RimTech/Stolar
The presenters will discuss a microwave technique for detecting ice build-up on wing surfaces of commercial airlines and highway bridges. A microstrip patch antenna serves as the sensor, evaluating changes in the resonance frequency and impedance dependent upon overlying layers of ice/water and glycol mixtures.

A Versatile Nondestructive Evaluation Imaging Workstation
E. James Chern, Goddard Space Flight Center, and David W. Butler, Paramax Systems Corp.
Chern and Butler have developed a combined ultrasonic C-scan and eddy current imaging workstation. The PC-based system includes a common mechanical control, data acquisition, and image processing software. It improves system efficiency, eliminates duplication of the computer and mechanical hardware, reduces setup time, and improves efficiency and capacity for future extensions.

A New High-Speed IR Camera System
Jeffrey Travis, Head, Detector Systems Section, Goddard Space Flight Center
Mr. Travis' camera features a 128 x 128 pixel IR detector array that exhibits high sensitivity over a broad band in the MWIR to LWIR wavelength regions and is capable of a 1000 frames/sec. data rate. The invention holds promise for commercial/industrial IR imaging or spectroscopic applications such as thermal machine vision for robotic manufacturing, observation of short-duration thermal events (i.e., combustion or chemical reactions), high-speed photography, and high-resolution surveillance imaging.

Universal Signal Conditioning Amplifier (USCA)
Jim Cecil, Electronics Engineer, Kennedy Space Center
A state-of-the-art USCA uses the information stored in a transducer's nonvolatile memory to automatically configure itself for maximum accuracy (12 bits) and resolution (16 bits). Use of the USCA minimizes setup times, improves reliability, and ensures more accurate results.

Wed., 7:00 - 9:00 pm

The Fourth Annual Technology Transfer Awards Dinner

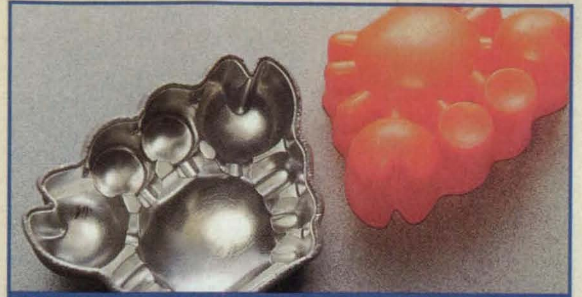
Guest speaker: Edward McCracken, Chief Executive Officer, Silicon Graphics Corp. (invited)

Thursday, December 7

Thurs., 8:30 - 11:00 am

Concurrent Workshops: International Technology Forum; Technology Alliance Opportunities in the Pacific Basin; Precision Casting Technologies for the Next Century

International Technology Forum
(panelists TBA)
In this highly-interactive session, top-level speakers from Canada, France, Italy, Austria, Russia, and other nations will introduce their portfolio of leading-edge technologies for transfer and provide key contacts and resources for follow-up.



INEL spray-forming technology (page K) enables the production of tooling at reduced cost. The metal mold (left) was produced in about five minutes by depositing atomized metal droplets directly onto the plastic pattern (right) using a benchscale apparatus.

Technology Alliance Opportunities in the Pacific Basin
(panelists TBA)
Discover specific opportunities for cooperative R&D and technology transfer with leading companies, universities, and government organizations in Pacific Rim countries. Learn the basics of doing business with these foreign partners.

Precision Casting Technologies for the Next Century
(panelists TBA)
Recent developments in applying sophisticated computer techniques to designing the casting process have shown that significant improvements can be attained in cost, quality, and time-to-market of cast products. Experts from the U.S. foundry, aerospace, and automotive industries as well as academia and NASA will discuss recent advances in these computer technologies. Specific examples and case histories will be presented to illustrate how these technologies are adding competitive value to the industry.

Thurs., 1:00 - 3:00 pm

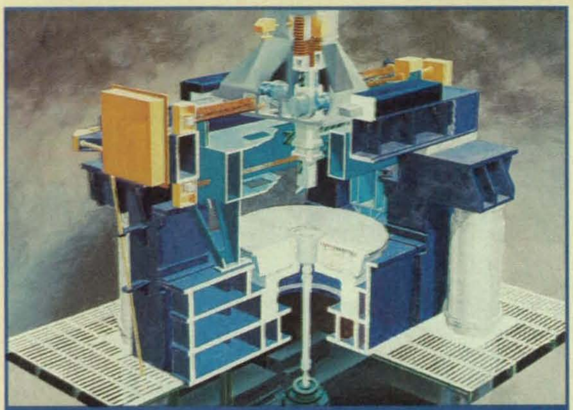
National Critical Technologies Concurrent Symposia

Advanced Manufacturing Part 3

Precision and Manufacturing at Lawrence Livermore
Theodore Saito, Acting Leader, Precision Engineering Program, Lawrence Livermore National Lab
Mr. Saito will describe the Energy lab's successful transfer of technology for diamond turning of optics, as well as other initiatives with significant commercial potential: precision engineering for machine tool manufacturing, lightweight materials manufacturing applied to the automotive and aerospace industries, nondestructive evaluation applied to production line quality control, precision motion control applied to flat panel displays, 3D microlithography applied to manufacturing, and computer modeling of materials.

Potential Capabilities of Reynolds Stress Turbulence Model in the COMMIX-RSM Code
F.C. Chang and M. Bottoni, Materials and Components Technology Division, Argonne National Lab
COMMIX-RSM performs steady-state/transient, single-phase, 3D analysis of fluid flow with heat transfer in a single- or multi-part engineering system. Developed for the analysis of thermal-hydraulic systems, it is suited for applications in radiation heat transfer, casting processes, power condensers, and other manufacturing systems.

An Improved Plating Process
John Askew, Chief, Process Engineering Branch, Benet Labs
An innovative process for the chromium plating of pipes and tubes eliminates the need for deep processing tanks or large volumes of



Lawrence Livermore engineers will describe the commercialization of their Large Optic Diamond Turning Machine (page M).

solutions, and negates associated environmental and safety concerns. Called Vessel Plating, the process can be monitored and controlled by computer, increasing reliability, flexibility, and quality.

The Unlimited Applications of Microtubes

Dr. Wesley Hoffman, Carbon Materials Research Group Leader, Phillips Lab

Air Force researchers have created microscopic tubes orders of magnitude smaller than existing tubing. The microtubes can be fabricated from any material, including high-temperature quartz or ceramics, and have application in areas as diverse as optics, medicine, and microelectromechanical devices. They offer the opportunity to miniaturize (even to the nanoscale) existing products and devices and to manufacture products that previously were impossible to produce.

Biotechnology/Medical Technology Part 2

Composite Redesign of Obstetrical Forceps

Stan Smeltzer and Seth Lawson, Engineers, Marshall Space Flight Center

Redesigned obstetrical forceps reduce the risk of injury to infants during delivery. The instrument is made of a thermoset composite that can be sterilized in an autoclave. Sensors embedded in the composite allow a physician to read the amount of force placed upon an infant's head, thereby eliminating the risk of unsafe pressure and injury.

The NASA/Baylor Left Ventricle Assist Device (LVAD)

Greg Aber, Propulsion Test Engineer, Johnson Space Center

LVAD is designed to provide either pulmonary or systemic support for patients with weak cardiac functions. Consuming little power and small enough for easy implantation, the axial flow device consists of a spinning impeller, a fixed flow straightener, and a fixed diffuser inside of a flow tube.

A Fuzzy Logic Controller for Hormone Administration Using an Implantable Pump

Dr. L. Stephen Cole, Group Chief Technologist, and George Wells, Jr., Jet Propulsion Lab

The JPL team will describe a fuzzy control algorithm developed to control an open-loop implantable insulin pump for use by insulin-dependent diabetics. The pump will obviate the need for patients to self-administer insulin by injection several times daily.

Monitor for "Status Epilepticus" Seizures

Mark Johnson, Electronics Engineer, and Dr. Thomas Simkins, Mechanical Engineer, Benet Labs

An electronic monitor detects the onset of "status epilepticus," a life-threatening seizure disorder affecting 3.5% of epilepsy sufferers, in which convulsions fail to cease until medically interrupted. The device senses motion peculiar to the disorder and activates a remote alarm via radio telemetry.

Environmental Technology Part 3

Gas Stream Purifier

S.J. Adam, McDonnell Douglas Aerospace

Corrosive acid, base, solvent, organic, inorganic, and water vapors as well as particulates are removed from an inert mixed gas stream in one step using only the gas flow across a purifier. Providing a 99% removal efficiency at both low (20 ppm) and high (>10,000 ppm) levels of contaminant vapors, the purifier will last for three-four months working at the 5-20 ppm contaminant level range and is not consumed by carbon dioxide or oxygen.

Using Spacecraft Trace Contaminant Control Systems to Cure Sick Building Syndrome

John Graf, Johnson Space Center

Techniques used to keep a spacecraft's interior uncontaminated can be applied to eliminate environmental pollution in buildings. Mr. Graf will describe NASA's trace contaminant removal systems employing ambient and high-temperature catalytic oxidation, absorption with LiOH and activated charcoal, absorption with a regenerative solid amine, photocatalytic oxidation, and plant photosynthesis.

A New Material For Removing Heavy Metals From Waste Water

Warren Philipp, Senior Research Chemist, and Kenneth Street, Chief, Chemical Sampling and Analysis Branch, Lewis Research Center; Joseph Savino, Technology Transfer Facilitator, Cleveland State University

A new high-capacity ion exchange material removes toxic metals from contaminated water. It can be made into many forms, including thin films, coatings, pellets, and fibers, and is suitable for water purification in waste water systems, lakes, ponds, industrial plants, and homes.

Dewatering of Contaminated River Sediments

Ronald Church and Carl Smith, Mining Engineers, U.S. Bureau of Mines

A new dredging technique designed for use in navigable waterways applies mining flocculation technology to reduce the resuspension of sediments. Instead of excavating material from the bottom of waterways, polymers are used to flocculate the fine particulate matter suspended in the water. The material settles to the bottom of a large clarifying tank, from which the "clean" water above is allowed to escape.

Materials Science Part 3

Advances in Carbon-Carbon Materials Technology

Howard Maahs, Head, Applied Materials Branch, Langley Research Center

Mr. Maahs will report on four recent advances in carbon-carbon composites technology: a doubling of the interlaminar strengths of 2D composites achieved by whiskerization of the fabric reinforcing plies; improved oxidation resistance and mechanical properties through use of matrix-phase oxidation inhibitors; increased oxidation resistance accomplished by applying, via chemical vapor deposition, compositionally-graded oxidation protective coatings; and markedly reduced processing times achieved through a novel process of carbon infiltration coatings deposition based on the use of the liquid phase precursor materials.

Casting of Weldable Graphite-Magnesium Composites with Built-In Metallic Inserts

Jonathan Lee, Marshall Space Flight Center

Technologists have produced low-cost and potentially weldable graphite-magnesium metal matrix composites (MMCs) using near-net-shape pressure casting. The components' built-in titanium metallic inserts provide an innovative approach for joining other MMC components through conventional techniques such as welding and brazing.

Design and Analysis of Composite Isogrid for Bridge Construction
James Koury, Phillips Lab; Piyush Dutta, Army Cold Regions Research and Engineering Lab; Richard Lampo, Army Construction Engineering Research Labs
Composite isogrids developed at the Phillips Laboratory hold several advantages over metal-stiffened structures: they are lighter (reducing lead times by a factor of five as well as labor costs for construction), are not susceptible to corrosion, have low thermal insulation values, and could be adapted for low-cost fabrication processes. The technology is ready for transfer to such applications as supports for bridges, building domes, and other commercial structures.

Improved Construction Materials for Polar Regions Using Microcellular Thermoplastic Foams
Daniel Cunningham, Plastics Engineer, Axiomatics Corp.
Microcellular foam (MCF) thermoplastics are an exciting development that will enhance U.S. competitiveness in the multi-billion dollar polymers market. Mr. Cunningham will explain how these lower-cost polymers could replace metals and composites in cold weather and polar region construction.

Video and Imaging Technology Part 2

Visually Optimized DCT Image Compression
Albert Ahumada and Andrew Watson, Research Scientists, Ames Research Center
Mr. Ahumada and Mr. Watson will demonstrate two new software technologies designed to alleviate the high costs of digital image storage. The first is a formula for computing quantization matrices that allows as much compression as possible, the second is a method for optimizing the compression matrix for individual images.

Voice and Video Transmission Experiment Using XTP and FDDI
John Drummond, Edwin Cheng, and Will Gex, Naval Command, Control, & Ocean Surveillance Center
Experiments have demonstrated reliable transmission of voice, data, and video over the FDDI (Fiber Distributed Data Interface)/XTP (Xpress Transfer Protocol) network. The technology can be applied to teleconferencing, voice, and electronic mail in high traffic networks, remote monitoring and control of manufacturing operations, data collection, and medical image transmission.

An Intelligent Interactive Visual Database Management System for Space Shuttle Closeout Image Management
Dr. James Ragusa, Associate Professor, University of Central Florida
A PC-based, networked system is designed to manage the tremendous amount of documentation photos NASA takes for each shuttle launch, replacing the costly use of hard copy prints and manual image manipulation. The prototype comprises a production station for image digitization, classification, and compression, a file server for image and data storage, and workstations for image decompression, retrieval, and display.

The Trustworthy Digital Camera: Restoring Credibility to the Photographic Image
Gary Friedman, Technical Group Leader, Jet Propulsion Lab
A proposed camera will produce images with encrypted digital signatures so that any retouching or alterations can be detected easily. The process would virtually eliminate counterfeit images and improve the credibility of photographs, especially in critical applications such as courtroom evidence.

How To Register

Complete the registration form on the next page and mail with check or money order (if applicable) to the Technology Utilization Foundation (c/o Brede Registration), or fax it with credit card data to (612) 378-6502. Deadline for preregistration is Friday, November 19.

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Complete Registration (includes symposia and exhibits, a ticket to the Awards Dinner, and a set of Tech 2003 proceedings)	$250	$295
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On-Site Registration Hours

Monday, Dec. 6	8:00 am - 5:00 pm
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United Airlines, official airline for Technology 2003, is offering a 10% discount off the unrestricted YUA coach fare or 5% off the lowest applicable fares. Attendees who book their tickets via UA's toll free number (1-800-521-4041) will be entered into a drawing for two round-trip tickets good in the continental U.S. and Hawaii. Refer to meeting ID# 537CB when reserving tickets.

Car Rental Discounts

Technology 2003 attendees are entitled to a special AVIS Rent-A-Car discount. Please call 1-800-331-1600 and refer to the Technology 2003 discount number: B711901. Discount is valid Nov. 30 - Dec. 16 and includes unlimited mileage.

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Disneyland is located minutes from the hotels and convention center. Discount tickets to Disneyland will be available for purchase in the Technology 2003 registration area during the show days.

Questions? Call Wendy Janiel at (800) 944-NASA or (212) 490-3999.

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Which of these products do you recommend, specify, or authorize the purchase of? (check all that apply)

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Electronic Components and Circuits

Locating Electron Traps in a CCD

The "pocket pumping" technique reveals traps smaller than one electron charge.

NASA's Jet Propulsion Laboratory, Pasadena, California

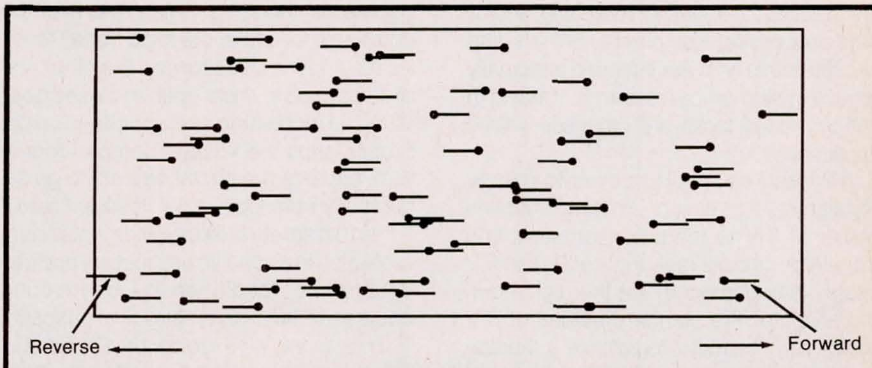
"Pocket pumping" is a technique for mapping the sizes of electron-trapping defects and the picture elements within which these traps are located in a charge-coupled device (CCD). There are two kinds of traps: forward and reverse (see figure). Pocket pumping relies on the fact that in terms of charges measurable by external circuitry, forward traps affect only the forward, while reverse traps affect only the reverse, transfer of charge along a row or column of picture elements. In essence, the charges in the picture elements are shifted back and forth many times to amplify the trapping effect by repetition. Even traps smaller than 1 electron can be detected by this method.

To diagnose a CCD by pocket pumping, it is necessary to alter the clock signals that control the transfer of charges among picture elements. Initially, the CCD is illuminated evenly at a low level to produce approximately 100 electrons of image charge in each picture element. (A larger or smaller charge could be used, depending on the size of the trap to be detected.) After the exposure, the CCD is clocked backward a specified number of rows or columns, then clocked forward the same number of rows or columns to the original positions.

This back-and-forth clocking is repeated a specified number of times, causing the buildup of signal charge in the picture elements that contain traps and the concomitant depletion of charge from nearby picture elements. The charges in the CCD are then read out in normal fashion, yielding a map in which the buildup of charge in each picture element is proportional to the size(s) of the trap(s) within it.

The figure illustrates a simple example of pocket pumping in a 10-picture-element segment of one column of a CCD. Picture element 5 contains a 7-electron reverse trap. At the initial exposure in time step 1, each picture element is filled with 10 electrons. In step 2, the device has been clocked backward one space; 7 of the 10 electrons from the previous cycle remain trapped in picture element 5, and 10 electrons have been shifted in from picture element 6, so that now there are 17 electrons in picture element 5. The 3 of the previous 10 electrons that were not trapped have been shifted to picture element 4.

During forward clocking in steps 6 through 9, charge is shifted away from the trap. This is followed by more buildup of charge by trapping in steps 10 through 13. The sequence of four steps of forward clocking followed by four steps of backward clocking is repeated until step 45, at which time all electrons initially contained in picture elements 1 through 4 have been pumped into picture element 5. Thus, the electronic image of the trap is the "spike" of charge in this picture element followed by zero charges in the four preceding picture elements. Step 46 is the beginning of a forward-clocking sequence in which the image is read out.



Time Step	Picture Elements 1	2	3	4	5	6	7	8	9	10	Mode
1	10	10	10	10	10	10	10	10	10	10	Exposure
2	10	10	10	3	17	10	10	10	10	10	Reverse
3	10	10	3	10	17	10	10	10	10	10	Reverse
4	10	3	10	10	17	10	10	10	10	10	Reverse
5	3	10	10	10	17	10	10	10	10	10	Reverse
6	10	3	10	10	10	17	10	10	10	10	Forward
7	10	10	3	10	10	10	17	10	10	10	Forward
8	10	10	10	3	10	10	10	17	10	10	Forward
9	10	10	10	10	3	10	10	10	17	10	Forward
10	10	10	10	0	13	10	10	17	10	10	Reverse
11	10	10	0	6	17	10	17	10	10	10	Reverse
12	10	0	6	10	17	17	10	10	10	10	Reverse
13	0	6	10	10	24	10	10	10	10	10	Reverse
14	10	0	6	10	10	24	10	10	10	10	Forward
21	0	0	9	10	31	10	10	10	10	10	Reverse
22	10	0	0	9	10	31	10	10	10	10	Forward
29	0	0	2	10	38	10	10	10	10	10	Reverse
30	10	0	0	2	10	38	10	10	10	10	Forward
37	0	0	0	5	45	10	10	10	10	10	Reverse
38	10	0	0	0	5	45	10	10	10	10	Forward
45	0	0	0	0	50	10	10	10	10	10	Reverse
46	10	0	0	0	0	50	10	10	10	10	Forward

Electrons Are Trapped in picture element 5 during the reverse transfer of charge. The repeated forward and reverse transfer of charge therefore causes electrons to be "pumped" into picture element 5 from nearby picture elements.

This work was done by James Janesick of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 42*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Jet Propulsion Laboratory [see page 24]. Refer to NPO-18349.

Instrumented Glove Measures Positions of Fingers

The position of each finger is resolved to 1 of 10 digital levels.

Lyndon B. Johnson Space Center, Houston, Texas

Figure 1 illustrates a glove that is instrumented with flat membrane potentiometers to obtain crude measurements of relative positions of fingers. The resistance of each potentiometer varies with the position of the associated finger; a translator circuit connected to each potentiometer converts the analog reading to 1 of 10 digital levels. The digitized outputs from all the fingers are then fed to indicating, recording, and/or data-processing equipment. Gloves and circuits of this type are intended principally for use in biomedical research, training in critical manual tasks, and other specialized applications.

A 9-V source supplies power to voltage regulator VR_1, which, in turn, supplies power at 5 V to the potentiometers and translator circuits (see Figure 2). The 5-V supply was chosen to set the digital output levels at the standard values of 0 V (logic "zero") and 5 V (logic "one"), thereby making them compatible with those of other transistor/transistor logic circuits that might be used to process the outputs.

The analog output of each membrane potentiometer (R_1) is fed via potentiometer R_2 to the input terminal (pin 5) of ten-level driver circuit Q_1. This analog input is scaled by adjusting R_2 so that the movement of the finger over its full range causes the voltage at pin 5 of Q_1 to vary between 0 and 1 V. Q_1 acts as an analog-to-digital converter. It contains ten open-collector switches driven by internal voltage comparators. When R_1 is 0, all the outputs of Q_1 are at the logic "one" level. As the finger moves toward the other end of its range (i.e., from open to closed position), the increasing analog voltage on pin 5 of Q_1 trips the voltage comparators in turn, causing the digital outputs to go sequentially from logic "one" to logic "zero." If the 10 discrete levels provide insufficient resolution in a specific application, one can double the resolution by connecting another 10-level driver circuit in cascade.

This work was done by Richard J. Bozeman, Jr., of **Johnson Space Center**. *For further information,* ***write in 8*** *on the TSP Request Card.*
MSC-21968

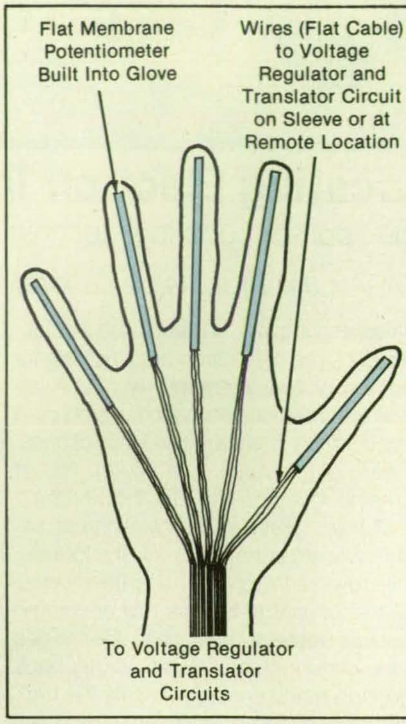


Figure 1. **Flat Membrane Potentiometers** are mounted in the glove to measure the positions of the fingers.

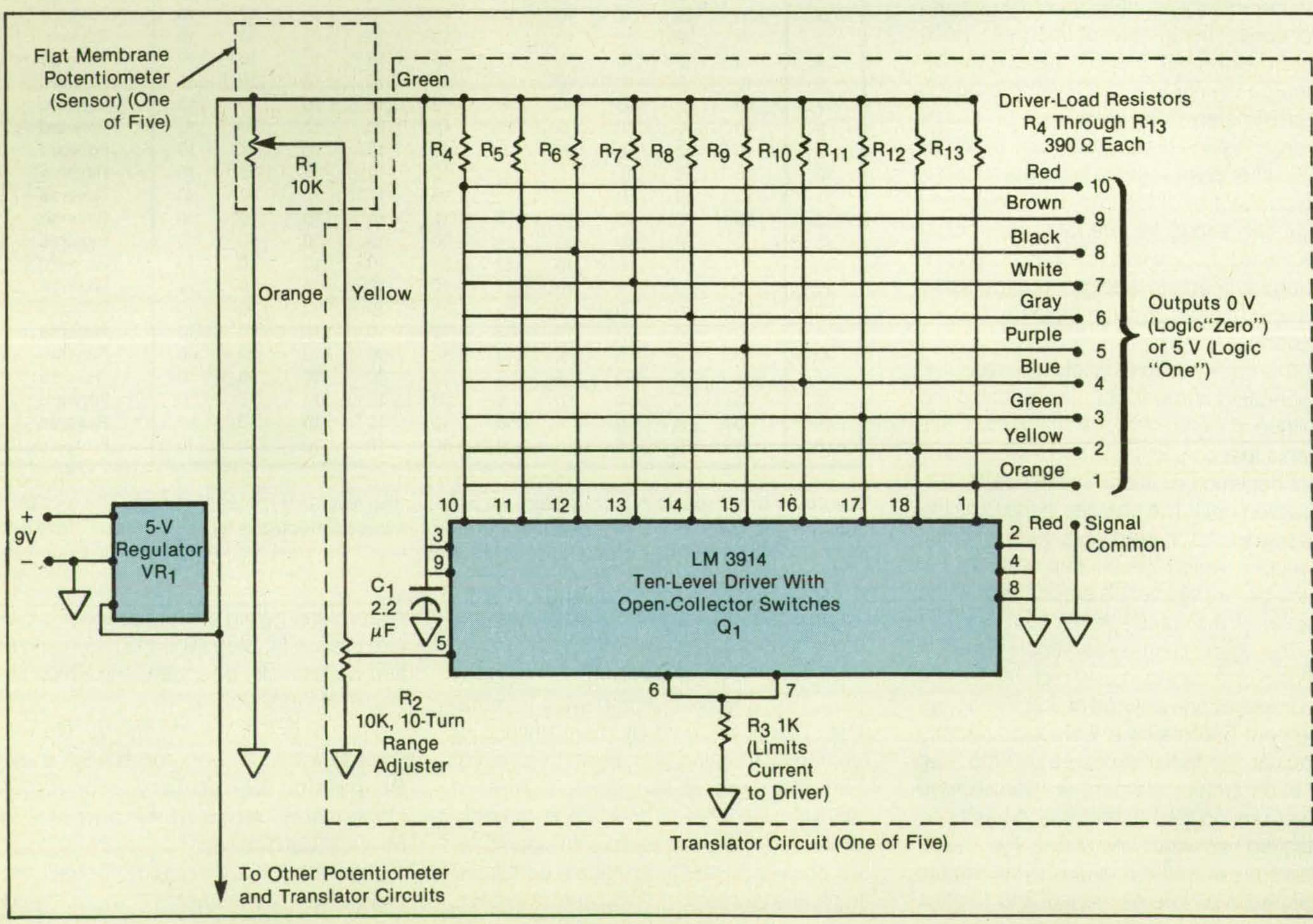
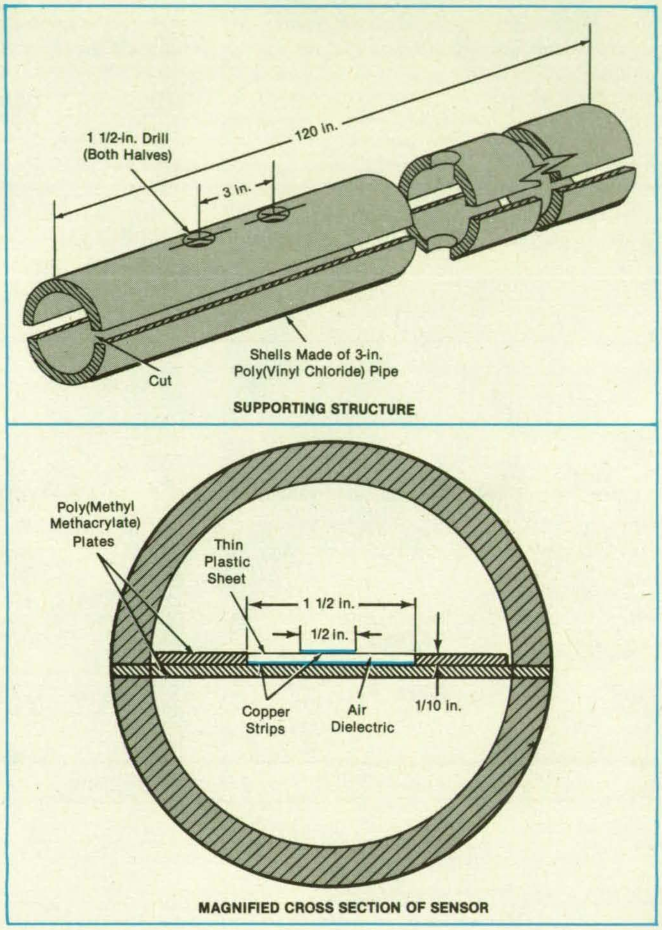


Figure 2. The **Translator Circuit** connected to each potentiometer converts its analog output to digital outputs that represent 10 discrete positions across the range of movement of the finger.

Microstrip-Transmission-Line Shock-Front Sensor

Velocities of low-overpressure shock waves can be measured by use of a repairable device.

Lyndon B. Johnson Space Center, Houston, Texas



The **Microstrip-Transmission-Line Shock-Front Sensor** can be made of readily available materials.

A sensor that consists of a microstrip transmission line in a special supporting structure can be used to measure the velocity of a shock front. As in other transmission-line shock-front sensors, a shock front propagating along the sensor gives rise to a discontinuity in the impedance of the transmission line. The motion of this discontinuity (and, thereby, the speed of the shock front along the transmission line) is measured by a reflectometer-type recording instrument connected to the transmission line.

Heretofore, crushable coaxial cables have been used to measure the speeds of propagation of shock fronts from explosions. Coaxial cables are not sensitive enough for low-overpressure shock fronts propagating far from explosions; they provide data only on intense near-blast fields. Furthermore, crushable coaxial cables are expensive, cannot be reused, and cannot be repaired in the field.

The microstrip-transmission-line sensor can measure the velocities of low-overpressure shock fronts and thus offers the dynamic range needed for measurements both far from and near explosions. It can be fabricated easily, is relatively inexpensive, and can be repaired in the field. In addition, its basic geometry can be modified easily, as needed.

The figure shows one version of the sensor, in which a microstrip transmission line is supported at the midplane of a perforated tube. The narrower copper transmission-line strip is attached by adhesive to a sheet of plastic, which supports it above the wider copper strip. The airgap between the copper strips constitutes the main body of transmission-line dielectric. The dimensions of the strips and gap are chosen to yield a characteristic impedance of 50 Ω, matching the impedance of a standard coaxial cable.

This work was done by Robert J. Leiweke and William C. Smith of Lockheed Engineering & Sciences Co. for **Johnson Space Center**. *For further information,* ***write in 4*** *on the TSP Request Card.*
MSC-21985

PC-Based Interface Circuit for Communication of Telemetric Data

The PCIO card reduces the amount of auxiliary equipment needed.

Goddard Space Flight Center, Greenbelt, Maryland

The PCIO card is an input/output interface-circuit card that enables a computer based on an ISA bus to transmit and receive high-speed, synchronous serial data and clock signals. The PCIO card is designed specifically to plug into an IBM PC-AT or compatible computer and to handle input and output of data in packet formats like those of telemetric data streams used throughout NASA and the aerospace industry.

The primary advantage of the PCIO card is that it performs many functions that were once performed by several pieces of larger, more-expensive signal- and data-processing equipment. With the advent of increasingly powerful personal computers, a new PC equipped with a PCIO card can now do the work a telemetric ground support system with a far more expensive computer and a rack full of support hardware performed several years ago.

The PCIO card is designed to be generic and flexible in the sense that it can be programmed, via software, to handle any of the data-stream formats with which it is likely to be presented. Telemetry streams generally consist of frames of data, with a synchronization pattern marking the start of each frame. Telemetry processing systems take in these blocks of data and perform various scientific and engineering processing functions on the data.

The input circuit of the PCIO card first searches for the telemetry-synchronization pattern, which is specified by use of a one-to-four-byte value programmed on the card via software control. After synchronization is found, the card loads the data words of the frame into a first-in/first-out (FIFO) buffer. (The length of the frame is another programmed value set by software control.)

The user software then reads the data from the buffer via an interrupt service routine, or by polling the input status register. The output circuit of the PCIO card takes data that the user program loads into a FIFO output buffer and clocks them out at a rate programmed by the user. The clock can be enabled and disabled under software control; the clock signal can also be commanded to be present only when data are present. This allows the receiving device to maintain lock on the data, even if gaps are present.

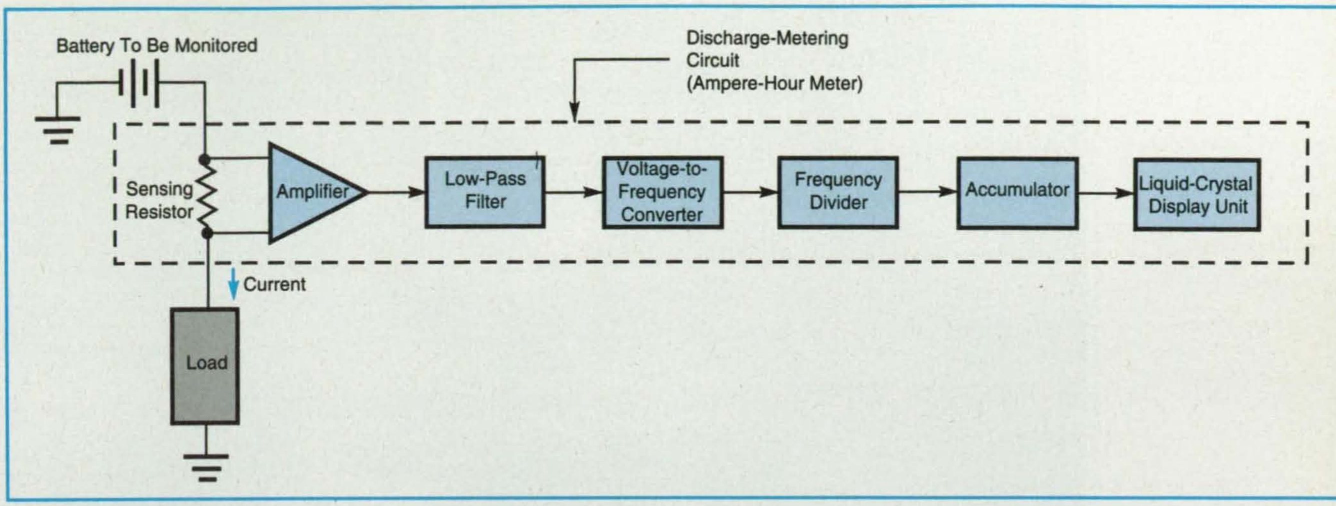
The transmitting and receiving circuits and buffers are totally independent, so that the PCIO card can send and receive data simultaneously. The programmable features of the PCIO card are set by loading values into various control registers. Statuses are read from status registers. Software to use the PCIO card can be written directly in such higher-level languages as C or Pascal, and no special device drivers are needed.

This work was done by Thomas P. Flatley of **Goddard Space Flight Center.** *For further information,* ***write in 18*** *on the TSP Request Card.*
GSC-13547

Ampere-Hour Meter for Rechargeable Battery

Monitoring helps prevent unnecessary recharging.

Langley Research Center, Hampton Virginia



The **Discharge-Metering Circuit** indicates the degree of discharge of the battery in ampere-hours or other suitable units of electric charge. It is small and consumes only 9 mW from an internal 6-V battery.

A low-power analog/digital electronic circuit meters the discharge of a storage battery in ampere-hours. Metering of the discharge is especially desirable in the case of a rechargeable nickel/cadmium battery to prevent loss of capacity: A nickel/cadmium battery exhibits a memory effect in that it loses charging capacity when recharged after incomplete discharge. Furthermore, excessive charge/discharge cycling can shorten the lifetime of such a battery. By metering the discharge, one obtains an indication of the state of charge of the battery and can then avoid unnecessary recharging, thereby maintaining the capacity of the battery and prolonging its life.

The discharge-metering circuit includes a sensing resistor in series with the load in the discharge path of the bat-

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tery to be monitored (see figure). A voltage proportional to the discharge (load) current is developed across the sensing resistor. This voltage is amplified, low-pass-filtered, and fed to a voltage-to-frequency converter.

The output of the voltage-to-frequency converter is a sequence of pulses at a rate of repetition proportional to the low-pass-filtered load current. A digital frequency divider scales the pulse-repetition rate to the desired engineering unit of charge — for example, 1 ampere-hour per pulse. The output pulses from the frequency divider are counted, and the count (e.g., accumulated ampere-hours) is indicated on a liquid-crystal display unit.

The discharge-metering circuit contains complementary metal oxide/semiconductor (CMOS) integrated circuits. These circuits and the liquid-crystal display unit consume little power: the discharge-metering circuit consumes only 9 mW. It is powered by a small commercial 6-V dry-cell battery, which can last several months at the 9-mW rate. Because of its small size and low power consumption, it should be useful in such applications as portable video cameras, communication equipment on boats, portable audio equipment, and portable medical equipment.

This work was done by John S. Tripp, Timothy D. Schott, and Ping Tcheng of **Langley Research Center**. *For further information,* ***write in 39*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 24]. Refer to LAR-14902.

High-Energy-Density Electrolytic Capacitors

Reductions in weight and volume would make new applications possible.

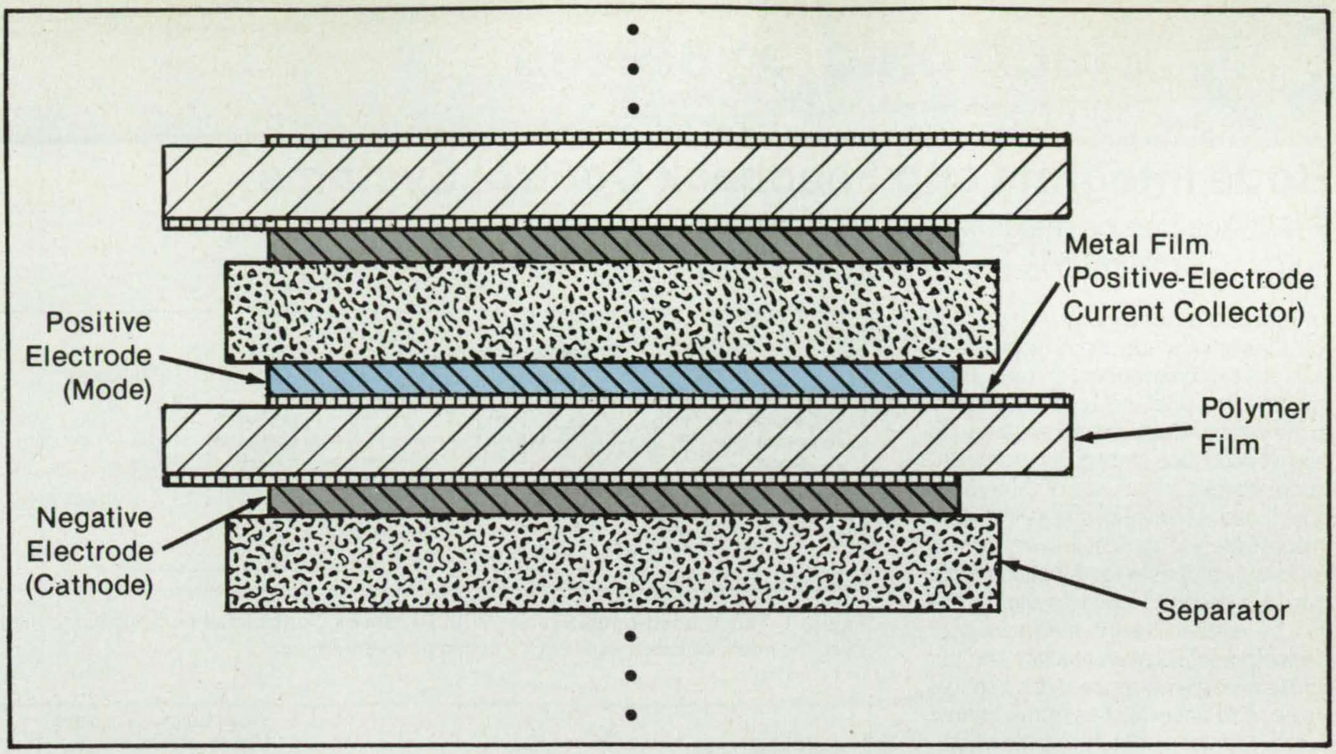
NASA's Jet Propulsion Laboratory, Pasadena, California

Supercapacitors and improved ultracapacitors are advanced electrolytic capacitors that are being developed for use as electric-load-leveling devices in such applications as electric vehicle propulsion systems, portable power tools, and low-voltage pulsed power supplies. One primary advantage of these capacitors is that they offer power densities much higher than those of storage batteries. Another advantage is that, unlike batteries, these capacitors can be used in pulse mode, with short charge and discharge times.

The supercapacitors and improved ultracapacitors are derived from commercially available ultracapacitors, which, in turn, are derived from battery technology. The supercapacitors and improved ultracapacitors are made of lightweight materials and incorporate electrode/electrolyte material systems that are capable of operation at voltages higher than those of previous electrode/electrolyte systems. Furthermore, by use of innovative designs and innovative manufacturing processes, they can be made in a wide range of rated capacitances and in rated operating potentials that range from a few to several hundred volts. Ultracapacitors with gravimetric energy densities of 10 Wh/kg, gravimetric power densities of 1 kW/kg, and volumetric energy densities greater than 15 Wh/L are feasible; the corresponding feasible energy and power densities of supercapacitors are even higher.

As in a battery, the cells of an improved ultracapacitor are connected in series to obtain the required operating potential. The anode of one cell and the cathode of the next cell in series or parallel are supported on opposite sides of a film, several microns thick, of capacitor-grade dielectric polymer that has a high breakdown voltage: a metal film deposited on each side of the polymer film serves as the current collector and support for the positive electrode (anode) or negative electrode (cathode) on that side (see figure). The electrode is formed on each side by coating the metal film with a mixture of high-surface-area carbon and an elastomeric electrolyte binder. A thin polymeric electrolyte (ion-conducting) separator is placed between the anode and the cathode in each cell. The permeable electrodes and separator are filled with a nonaqueous electrolyte solvent/salt system like acetonitrile/tetrabutylammonium tetrafluoroborate. Such a cell can be operated safely at potentials up to 5 V; the only voltage-limiting factor is the oxidative/reductive stability of the solvent and salt.

A supercapacitor is similar, except that, in the cathodes, the carbon electrode material is replaced by a transition-metal oxide or a hydrous oxide. In a supercapacitor, the Faradaic transfer of charge provides additional charge-storage capacity.



Lightweight Thin Metalized Polymer Film replaces a heavier metal current-collector structure in a prior ultracapacitor. The improved ultracapacitor and supercapacitor structure can store energy at greater density.

This work was done by Shiao-Ping S. Yen and Carol R. Lewis of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 9*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 24]. Refer to NPO-NPO-18568

Bode Integrals and Feedback Control Systems

Feedback can be maximized in desired frequency ranges.

NASA's Jet Propulsion Laboratory, Pasadena, California

Four of the Bode integrals constitute the basis of a method of optimizing the design of a feedback control system. These integrals, first published by Hendrik Bode in the year 1940, express frequency-domain relationships among, and constraints upon, various measures of attenuation and phase in feedback amplifiers. These integrals are also applicable to similar magnitudes and phases (as functions of frequency) in feedback control systems. They can be used to design feedback compensators to maintain stability and performance in the presence of disturbances, noise, and uncertainties in the characteristics of the plant to be controlled.

The basic design problem is to find the appropriate transfer function, $C(s)$ (where s is the Laplace-transform complex-frequency variable), for the compensator in a feedback system like that shown in Figure 1. The open-loop transfer function, $L(s)$, is given by $L(s) = C(s)P(s)$, where $P(s)$ is the transfer function of the plant to be controlled. In addition, the system may include a prefilter of transfer function $R(s)$. Good engineering practice dictates that one provide adequate stability margins and rejection of disturbances and should not sacrifice them to satisfy rise-time, overshoot, or settling-time requirements: instead, one should adjust $R(s)$ to satisfy these requirements as well as possible.

The four Bode integrals in question are valid provided that certain conditions (e.g., that $L(s)$ be of minimum phase) are satisfied. These equations are as follows:

$$(1)\quad \phi(\omega_a) = \frac{1}{\pi}\int_{-\infty}^{\infty} \frac{d \ln |L|}{du} \ln \coth\left|\frac{u}{2}\right| du$$

$$(2)\quad \int_0^{\infty} \ln |F| \, d\omega = 0$$

$$(3)\quad \int_{\omega=0}^{\omega=1} (\ln |L| - \ln |L|_{\infty}) d \arcsin\omega = -\int_1^{\infty} \frac{\phi}{\sqrt{\omega^2-1}} d\omega$$

$$(4)\quad \int_{-\infty}^{\infty} \frac{\phi}{\omega} d\omega = \pi\{\ln |L|_{\infty} - \ln |L|_0\}$$

where the magnitude $|L|$ and phase ϕ are related by $L = |L| e^{j\phi}$, the magnitude of the return difference (also loosely called the "feedback") is given by $|F| = |1 + L|$, where ω = is the real angular frequency,

$$u = \ln \frac{\omega}{\omega_a}$$

$$|L|_0 = |L(j\omega)|_{\omega=0}$$

and

$$|L|_{\infty} = |L(j\omega)|_{\omega=\infty}$$

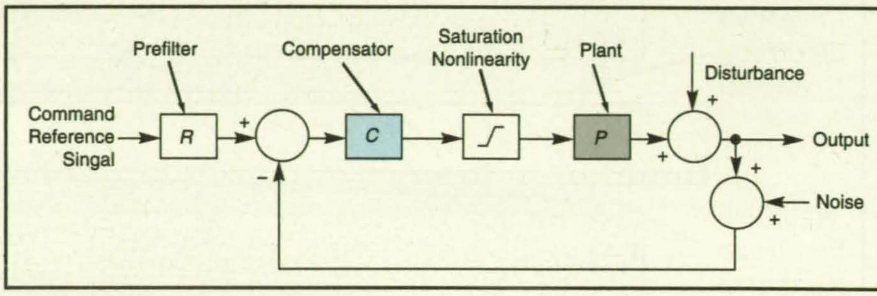


Figure 1. This **Closed-Loop System With Feedback Control** can be designed to minimize the effect of disturbances in a working frequency band.

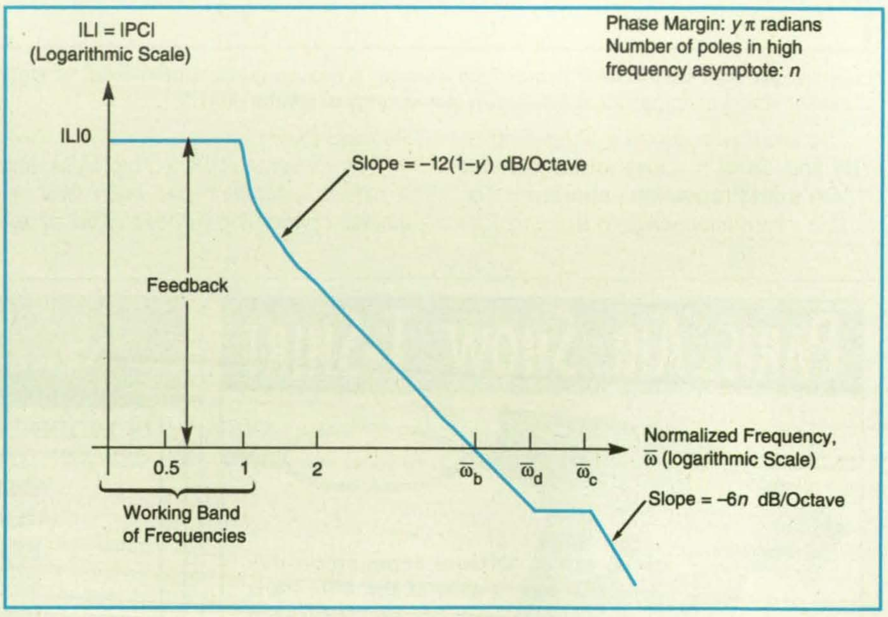


Figure 2. The **Bode Ideal Cutoff** is an idealized frequency-response curve that can be used to optimize the design of the feedback control system.

Figure 2 illustrates a particular frequency response known as the Bode ideal cutoff. Indicated on this plot is a working band of frequencies at which the feedback is to be maximized to meet the design objectives. It has been found that by use of a number of relatively simple equations and without evaluating the Bode integrals explicitly, one can maximize the gain of the feedback loop subject to the Bode integral constraints. This can be done with the help of the Bode ideal cutoff, which makes it possible to start with the bandwidth, the high-frequency-rolloff constraints, and the uncertainties in the mathematical model of the plant, which set the stability margins, and then maximize the feedback (loop gain or disturbance rejection) over the band of frequencies at which disturbances are most significant.

The Bode-ideal-cutoff design procedure can be effected with pencil and paper and without requiring that the compensator be of a certain fixed order or even a rational function of frequency. In a test case, this method was applied to the preliminary design of feedback in a

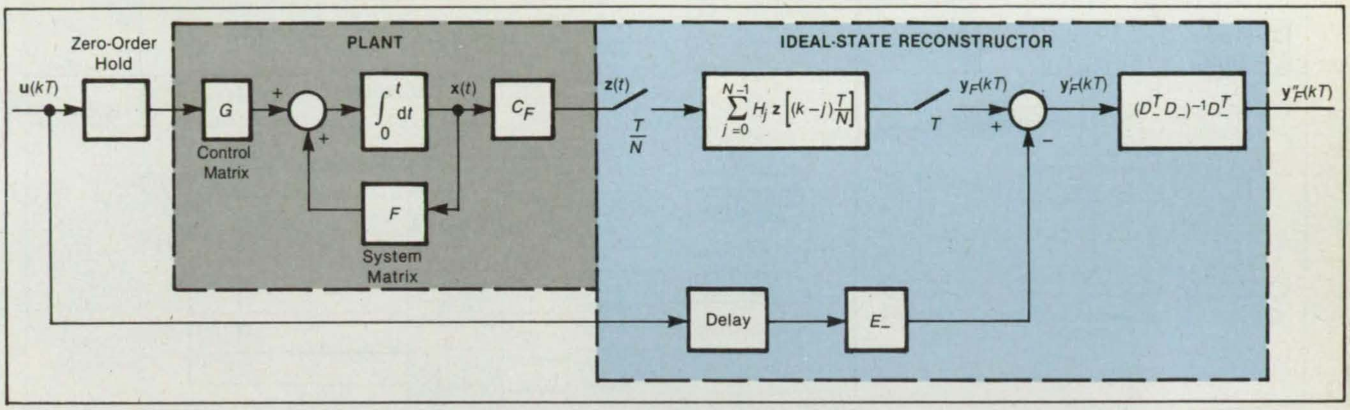
wave-front-tilt control by two mirrors on an interferometer in outer space. The resulting design example illustrates how the Bode-ideal-cutoff design procedure takes account of bandwidth and sensor-noise constraints and uncertainties via stability margins, and then maximizes the feedback (loop gain or disturbance rejection) over a prescribed frequency band.

This work was done by Glen J. Kissel of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 46*** *on the TSP Request Card. NPO-18331*

Ideal State Reconstructor for Control System

This subsystem does not add new states, eigenvalues, or dynamics.

Marshall Space Flight Center, Alabama



The **Ideal State Reconstructor** estimates the state of the plant at sampling intervals of period D, without introducing spurious dynamics into the system. Provided that certain design requirements are met, the ideal state reconstructor can estimate the state exactly.

The ideal state reconstructor is a conceptual subsystem of a deterministic digital control system that estimates the state of the controlled plant periodically at discrete sampling intervals of duration T. This subsystem is called "ideal" for two reasons: (1) if the parameters of the plant are known exactly, then the output of this subsystem is an exact representation of the state of the plant. (2) Although this subsystem affects the measurement equation (the processing of the measured output of the plant), it does not affect the plant equation (the dynamics of the plant) and it does not give rise to additional states or eigenvalues of the overall plant/controller system.

Of course, the output of the ideal state reconstructor could be fed to another control subsystem that does affect the dynamics. However, it is important to distinguish between the ideal state reconstructor and a prior nonideal subsystem called the "state observer," which estimates the state at the sampling instant but is also part of a feedback control loop. Because the state observer is a dynamical subsystem, it does add states and eigenvalues, and can thus affect the stability of the overall system. Furthermore, the estimate of the state observer is usually only an approximation of the true state, and a poor approximation early in the state-reconstruction process.

The ideal state reconstructor (see figure) is based largely on the concepts described in "State-Variable Representations for Moving-Average Sampling" (MFS-28405), *NASA Tech Briefs*, Vol. 15, No. 1 (January 1991), page 48. The plant is a continuous-time system, the dynamics of which are represented by system matrix F. The digital control vector at intervals kT (where k is an integer) is converted via a zero-order hold into continuous-time control vector $\mathbf{u}(t)$ (where t = time), which, in turn, is fed to the plant. The continuous-time state of the plant, $\mathbf{x}(t)$, manifests itself externally via output matrix C_F, which yields continuous-time output $\mathbf{z}(t)$.

In the ideal state reconstructor, $\mathbf{z}(t)$ is sampled at N equal subintervals of the fundamental sampling period T, and the sample in each subinterval j is weighted by a matrix H_j, resulting in a moving-average-prefiltered measurement vector $\mathbf{y}_F(kT)$. Meanwhile, the control vector is delayed by one sampling period T and multiplied by a constant matrix E_-, and the vector product is subtracted from $\mathbf{y}_F(kT)$ to obtain a modified moving-average-prefiltered measurement vector, $\mathbf{y}'_F(kT)$. Then by use of another matrix, D_-, $\mathbf{y}'_F(kT)$ is converted to $\mathbf{y}''_F(kT)$, which is the final estimate of the state vector at time kT.

The design of a specific ideal state reconstructor involves the choice of H, E_-, and D_-. H can be chosen somewhat arbitrarily: for example H can be constructed by catenating individual weighting matrices H_j; or it can be designed as a multiple-input/multiple-output low-pass filter to reduce noise; or, if it is square, it can be an identity matrix. Once H is chosen, E_- is computed as the product of H and another matrix, β, that is, in turn, computed from C_F, G, and the time integral of a state-transition matrix that can be expressed as a matrix exponential of F. D_- is the product of H and yet another matrix, α, computed from C_F and the matrix exponential of F.

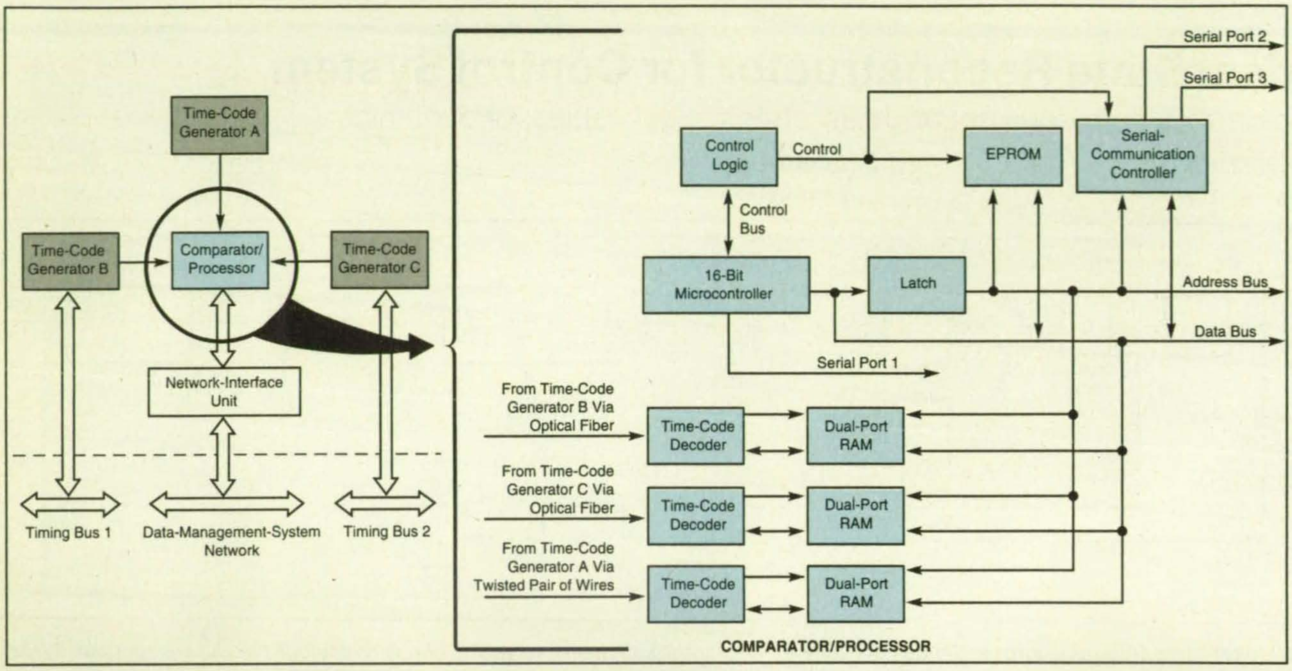
The requirements that must be satisfied for the ideal state reconstructor to reconstruct the state of the plant exactly are as follows: The plant matrices F, G, and C_F must be known exactly to determine E_- and D_-. The number of rows q, in the weighting matrices H_j, j = 0, 1,..., $N - 1$ must be greater than or equal to the number of states in the plant, n. The $q \times n$ matrix D_- must have rank n. So long as these requirements are met, there are no other restrictions on the ideal state reconstructor, including its weighting matrices. This is very desirable because it means there are a multitude of ways to choose the weighting matrices and still achieve exact state reconstruction.

This work was done by Michael E. Polites of **Marshall Space Flight Center**. *For further information,* ***write in 107*** *on the TSP Request Card. MFS-28438*

System Measures Errors Between Time-Code Signals

Errors between 1-second clock pulses are resolved to 2 µs.

Lyndon B. Johnson Space Center, Houston, Texas



This **System Measures the Timing Errors** between signals produced by three asynchronous time-code generators.

The time-comparator/digital-processor system shown in the figure decodes the signals from three time-code generators and measures the timing errors between them. The time code in question is an international standard code of the Consultative Committee for Space Data Systems (CCSDS), and it includes clock pulses at 1-second intervals. The three CCSDS time-code generators in question, denoted as A, B, and C, run asynchronously with respect to each other. The time-comparator/digital-processor ("comparator/processor," for short) system measures the difference between the times of corresponding clock pulses B and A and the difference between the times of corresponding clock pulses C and A in real time to a resolution of 2 µs.

The heart of the system is a 16-bit microcontroller, which is constructed as a single-chip integrated circuit and includes a powerful 16-bit central processing unit tightly coupled with (1) an 8-kbyte electrically programmable read-only memory (EPROM), in which the controlling software resides; (2) a 232-byte random-access memory (RAM), in which data are stored; (3) two independent timers; (4) a serial-communication port; (5) baud-rate generators; and (6) a 10-bit analog-to-digital converter. The incorporation of all of these resources into the microprocessor integrated circuit reduces significantly the number of components in, and the power consumed by, the system.

Each of the three incoming time-code signals is received and preprocessed by a special CCSDS-time-code-decoding circuit. This circuit decodes the CCSDS serial-data signal and converts the decoded serial time data into byte-wide parallel data for output to one of three dual-port RAM's. It also extracts the control signals necessary to write the data into the dual-port RAM and to interrupt the processor to read data at the end of each frame of data.

Three serial-communication ports constitute control and data-communication interfaces between this and other systems. One of these ports is the one in the microcontroller. The other two ports are contained in a serial-communication controller. These two ports can be configured via software to suit any of a variety of serial-communication applications. The serial-communication controller includes components that perform several sophisticated internal functions: these include on-chip baud-rate generators, digital phase-locked loops, and crystal oscillators, all of which significantly reduce the need for external logic. The built-in versatility of the serial-communication controller can be used to implement rapid, synchronous, serial data-communication protocols when the need for rapid transfer of data arises.

The timing errors between the time-code signals are computed with the help of one of the timers in the microcontroller: a 16-bit timer that operates with a 12-MHz processor clock, yielding the 2-µs resolution. The errors between the time-code signals are computed continuously and stored in the on-chip RAM, for transmission on request via a network-interface unit to an associated data-management system.

The basic principle of computation of the timing errors is as follows: The central processing unit in the microcontroller constantly monitors the time data received from the time-code generators for changes in the 1-s time-code intervals. In response to any such change, the microprocessor buffers the count of its 16-bit internal timer.

Every time that time signal A indicates the passage of another 1-s clock interval ("seconds time," for short), a new reference count is established for computing the time error. Following the detection of a change in the seconds time of time signal B or C, the central processing unit computes the time in microseconds between the instants of the change in the seconds counts of time signal A and time signal B or C, respectively. This error is computed every second and stored in the microcontroller RAM.

This work was done by David Cree of **Johnson Space Center** *and C.N. Venkatesh of Lockheed Engineering & Sciences Co. For further information,* ***write in 31*** *on the TSP Request Card. MSC-22115*

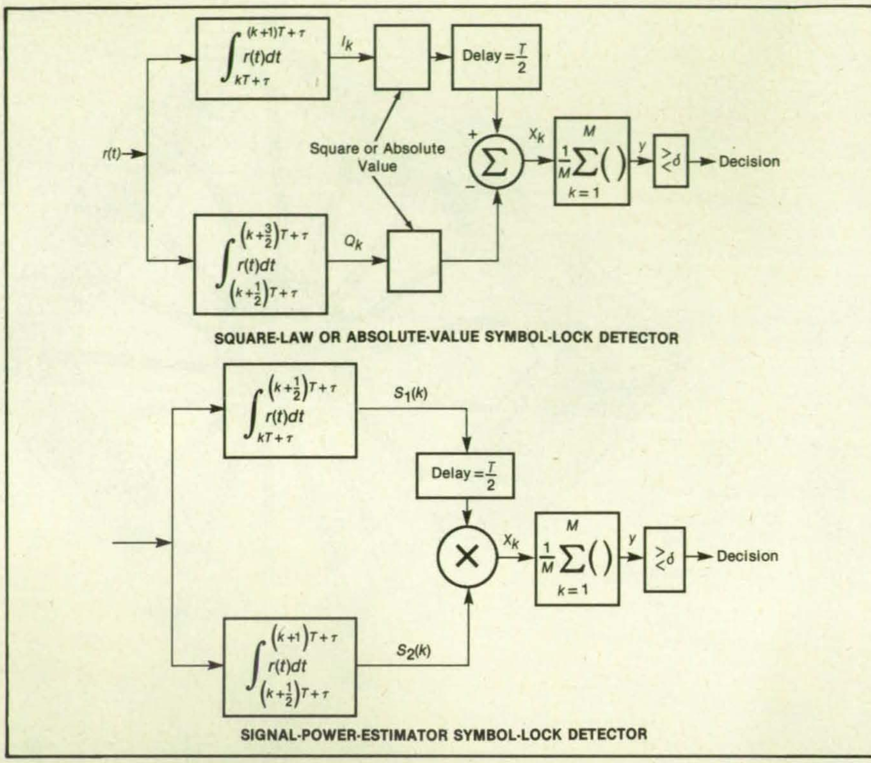
Three Alternative Symbol-Lock Detectors

Some performance is traded off against simplification.

NASA's Jet Propulsion Laboratory, Pasadena, California

Three symbol-lock detectors have been proposed as alternatives to two older symbol-lock detectors in advanced receivers that process non-return-to-zero binary data signals. A symbol-lock detector is an analog and/or digital subsystem of a receiver that decides, according to a preset criterion, whether the receiver is in lock in the sense that its symbol-detecting operation is synchronized with the binary-symbol period T or whether it is slipping symbol cycles. If the receiver is slipping symbol cycles, then one cannot rely on its detected symbols. Thus, a symbol-lock detector is an important part of the receiver because it contributes to the decision of whether to accept or reject the detected symbols.

The figure illustrates the various symbol-lock detectors. In each case, the received signal is assumed to have been mixed with perfect carrier and subcarrier reference signals, yielding a baseband signal $r(t)$ (where t = time) that is fed to the symbol-lock detector. One of the older symbol-lock detectors is that of the square-law type, in which $r(t)$ is integrated during symbol periods that overlap by $T/2$, differences between squares of integrals are computed, and a decision is made after an observation period of M symbol periods (typically, $M >> 1$). Another of the older symbol-lock detectors is that of the absolute-value type, which is similar to that of the square-law type except that the absolute values (instead of the squares) of the integrals are used. In each symbol-lock detector of the square-law or absolute-value type, two integrators are needed because two different integrations must be performed simultaneously.



The **Five Symbol-Lock Detectors** are represented by two generic block diagrams. τ denotes the timing error: $\tau = 0$ denotes perfect synchronization of the receiver with the received symbols.

Two of the proposed symbol-lock detectors would perform operations similar to those of the older square-law and absolute-value types. However, the integrals would be computed during nonoverlapping symbol periods and, therefore, only one integrator would be needed in each such detector. The proposed detectors would thus be simpler, but one would expect their performances to be worse because the noises in overlapping samples are correlated, whereas the noises in nonoverlapping samples are not correlated.

The third proposed symbol-lock detector is that of the signal-power-estimator type. In this detector, the signal is integrated during successive half symbol cycles, and therefore only one integrator is needed. The half-cycle integrals are multiplied to eliminate the effect of the symbol polarity, and the products are accumulated during an M-cycle observation period to smooth out the estimate of the signal power. If the estimated signal power exceeds a threshold, δ, then lock is declared.

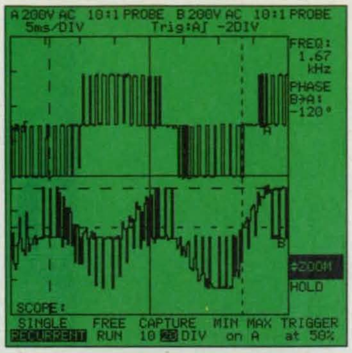
The performances of the various lock detectors were compared by theoretical analysis and computer simulation. The comparisons were made with respect to the detector signal-to-noise ratio (SNR) and the probability of detection of lock as a function of symbol SNR for a given probability of false indication of lock and a fixed observation period. The analysis investigates the effects of symbol-timing error on lock-detector performance when lock indications occur once per inverse-symbol-synchronizer loop bandwidth, as well as when they occur once per several inverses of the loop bandwidth. Also, the case of threshold setting in the absence of signal is considered. The older and more-complicated symbol-lock detectors were found to perform better under most conditions, as expected. In particular, the square-law detector with overlapping intervals outperformed all others when the threshold for the decision regarding the attainment of lock was set in the presence of signal, independently of the relationship between the bandwidth of the symbol-detection loop and the observation period. However, the signal-power-estimator detector outperformed all the others when the threshold was set in the presence of noise only. The interdependence between the loop bandwidth and the detector performance, measured in terms of probability of detecting lock, depends on the scenarios that one is trying to distinguish. For example, in radar applications the detector distinguishes between the presence or absence of a signal. It is shown that in this case the detector performance is independent of the loop bandwidth. In other applications — e.g., deep space — the signal is assumed to be always present. In this case, the detector distinguishes between whether the loop is locked or slipping cycles. The performance of the lock detector when the loop is cycle slipping is thoroughly quantified for the first time.

This work was done by Mazen M. Shihabi, Sami M. Hinedi, and Biren N. Shah of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 6*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 24]. Refer to NPO-18521.

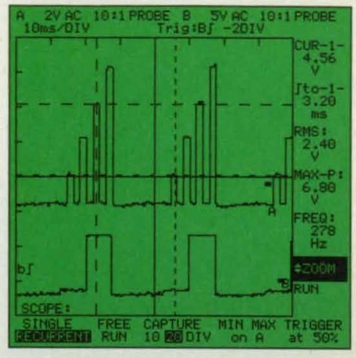
A DAY IN THE LIFE OF SCOPEMETER®.

6:42 AM, Motor in #2 shaft overheating.
Dual channel shows incorrect drive signal.

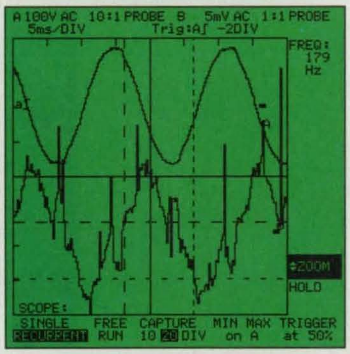


8:23 AM, Security Monitor not working.
3-1/2-digit DMM indicates bad ground.

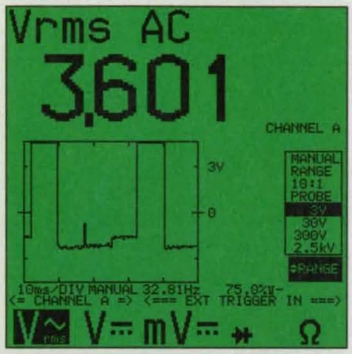
9:25 AM, Conveyor Stepper Control fails.
Cursors help find broken sync connection.



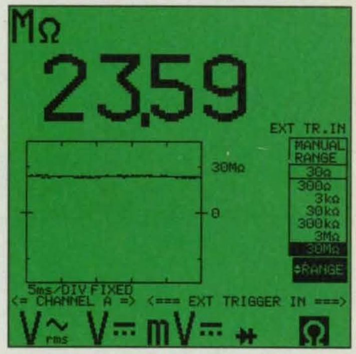
10:57 AM, Intermittent Auditorium lighting.
Waveform shows too much noise.



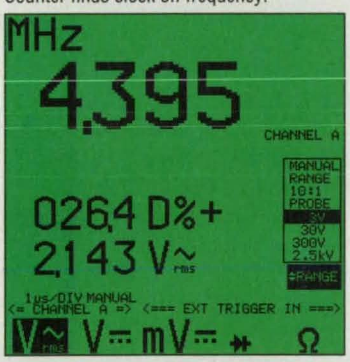
11:17 AM, 5V Control Signal is bad.
Scope display reveals -DC offset.



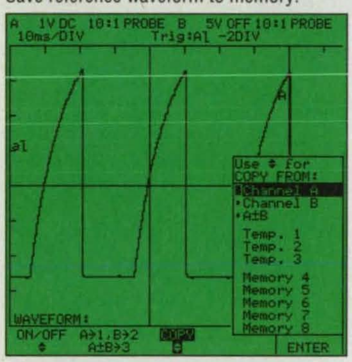
12:58 PM, Air Conditioner overheating.
Resistance shows corroded connection.



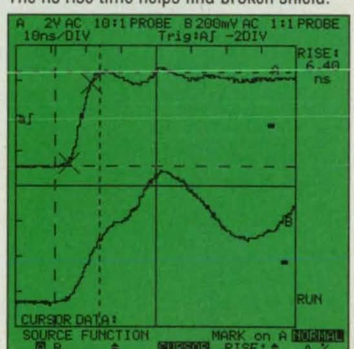
1:22 PM, Copier toning uneven.
Counter finds clock off frequency.



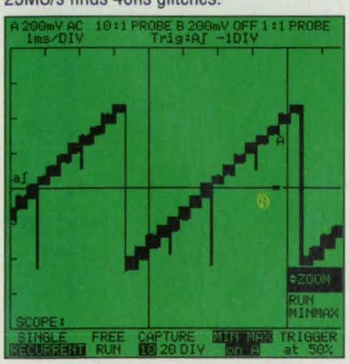
2:14 PM, Testing Power Inverter loads.
Save reference waveform to memory.



3:12 PM, Copier fails, again!
The ns rise time helps find broken shield.



4:05 PM, Salesman presents demo board.
25MS/s finds 40ns glitches.



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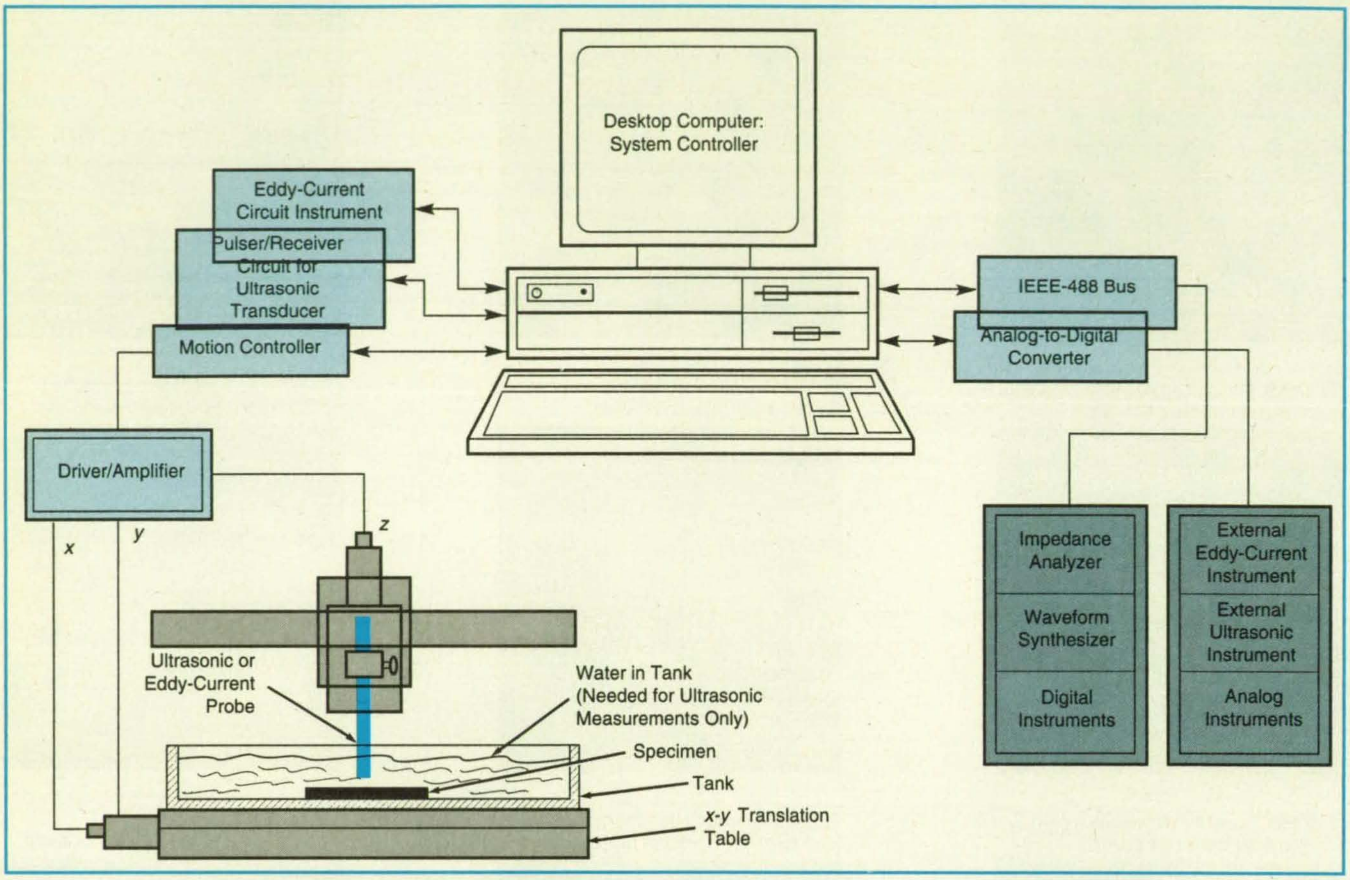
Unified Ultrasonic/Eddy-Current Data Acquisition

Parts of two nondestructive-evaluation systems are combined for economy and efficiency.

Goddard Space Flight Center, Greenbelt, Maryland



A **Variety of Plug-In Cards** adapt a desktop computer to ultrasonic and/or eddy-current imaging.

An imaging station for detecting cracks and flaws in solid materials has been developed that combines both ultrasonic C-scan and eddy-current imaging, which are two of the most widely used techniques for nondestructive evaluation (NDE). The incorporation of both techniques into the one system eliminates duplication of computers and of mechanical scanners; unifies acquisition, processing, and storage of data; reduces setup time for repetitious ultrasonic and eddy-current scans; and increases the efficiency of the system.

The same mechanical scanner can be used to maneuver either an ultrasonic or an eddy-current probe over a specimen and acquire point-by-point data. For ultrasonic scanning, the probe is linked to an ultrasonic pulser/receiver circuit card, while, for eddy-current imaging, the probe is linked to an impedance-analyzer circuit card. Both ultrasonic and eddy-current imaging subsystems share the same desktop-computer controller, which contains dedicated plug-in circuit boards for each (see figure).

The mechanical scanner includes a motor-driven x–y translation table with incremental linear encoders. The motors are controlled via a programmable multiaxis controller circuit card. For ultrasonic scanning, a water-filled tank on the table holds the specimen. For eddy-current scanning, the specimen is mounted directly on the table. The mechanical scanner and the computer communicate through an Industry Standard Architecture (ISA) bus.

The system can also be used with external ultrasonic, eddy-current, and other instruments. Measurement data from external instruments are transferred to the computer through an IEEE-488 interface bus. Analog data from external instruments are converted to digital data for processing by yet another plug-in circuit card in the computer.

This work was done by E. James Chern of **Goddard Space Flight Center** *and David W. Butler of Paramax Systems Corp. For further information,* ***write in 11*** *on the TSP Request Card.*
GSC-13553

Actively Controlled Magnetic Vibration-Isolation System

Vibrations at subhertz frequencies can be suppressed or induced.

Lewis Research Center, Cleveland, Ohio

A prototype magnetic suspension system with active control isolates an object (e.g., a package of scientific instruments) from vibrations in all six degrees of freedom at frequencies as low as 0.01 Hz. The system is designed specifically to protect instruments aboard a spacecraft by suppressing vibrations to microgravity levels; the basic control approach could be used for such terrestrial uses as suppression of shocks and other vibrations in trucks and railroad cars.

The prototype system includes 12 magnetic actuators coupled to 6 relative-position sensors via a digital feedback loop. The actuators are also coupled to six inertial sensors in a feedforward loop. The control algorithms can be modified to make the magnetic suspension act as a multiple-degree-of-freedom shaker that imposes desired low-frequency vibrations while suppressing background disturbance vibrations of the base. The system can also be programmed to use inertial feedback, in such a way that it stabilizes the instrument package against direct disturbances.

A prior active vibration-isolation system designed for the same purpose suppressed vibrations at frequencies down to about 3 Hz. The primary advantages of this prototype system are its superior performance at frequencies below 3 Hz and its extension of the lower frequency limit to 0.01 Hz. However, this is not meant to be a general-purpose vibration-isolation system; it would not be cost-efficient for suppression of vibrations at higher frequencies, where a less expensive system would function as well.

This work was done by Carlos M. Grodsinky, Kirk A. Logsdon, Joseph F. Wbomski, and Gerald V. Brown of **Lewis Research Center**. *For further information,* ***write in 36*** *on the TSP Request Card. LEW-15530*

Frequency-Channelized Recovery of Timing

A frequency-domain equivalent of the delay-and-multiply operation is performed.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method of extracting the bit or baud rate of an excess bandwidth pulse-amplitude-modulated signal is based on a frequency-domain equivalent of the time-domain delay-and-multiply operation. The method involves the use of the outputs of a Fourier-transform-based, channelized receiver (heretofore, such receivers have been used to analyze narrow-band signals). Very little a priori knowledge of the parameters of the signal is needed, and processing of the signal by this method yields a spectral line at the pulse-repetition rate (bit rate or baud rate).

The processing is performed on the baseband pulse-amplitude modulation $X(t)$, which can be expressed as

$$X(t) = \sum_n a_n g(t - nT)$$

where t = time; a_n denotes real, independent, zero-mean, discrete-valued random variables; $g(t)$ denotes a real-valued pulse; T is the pulse-repetition period (baud interval); and n is an integer. The top part of Figure 1 illustrates the extraction of timing information by use of the older method, in which the time-domain delay-and-multiply operation is followed by a Fourier-transform operation. The bottom part of Figure 1 illustrates the extraction of timing information by use of the present frequency

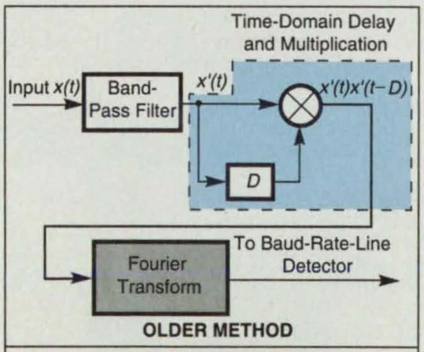


Figure 1. The **Frequency-Domain Convolution** of the newer method takes the place of the time-domain delay and multiplication of the older method.

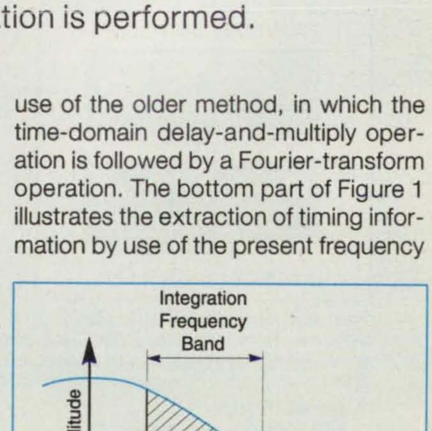


Figure 2. **Part of the Signal Spectrum** instead of the whole spectrum can be used (that is, the spectrum can be channelized) in the convolution to determine the baud rate.

channelized method, in which an N-point fast-Fourier-transform operation is followed by a frequency-domain convolution operation.

The frequency-domain convolution is equivalent to the time-domain delay and multiplication. The mathematical basis of the method includes two assumptions that, in practice, can be relaxed slightly without significant adverse effect: (1) The duration of each pulse is limited to T, and (2) the sampling frequency F_s is an integral multiple of the pulse-repetition frequency; or, equivalently, the number of sampling periods, T_s, in the pulse-repetition period, T, is an integer. Under these assumptions, the result of the frequency-domain convolution is approximately a series of spectral lines at multiples of the baud rate.

To maintain equivalence with the time-domain delay and multiplication and thereby maximize the detectability of the baud-rate spectral line, one would have to compute the convolution integral over all frequencies from $-\infty$ to $+\infty$. In this method, however, smaller integration bandwidths are used to simplify implementation; the middle frequency and the width of the integration frequency band are chosen according to a performance-vs.-implementation tradeoff. In general, only a portion of the spectrum of each signal need be channelized (see Figure 2) for detection of the baud rate.

A "bootstrap" or iterative process for detection and estimation of the baud-rate spectral line begins with the computation of the channelized frequency convolution by use of an assumed delay $D = 0$ to obtain a preliminary estimate of $1/T$. Then, using this estimate, one chooses $D = T(\text{estimated})/2$ and recomputes the channelized frequency convolution with increasing integration bandwidths to obtain refined estimates of the baud rate.

This work was done by Edgar H. Satorius of Caltech and James J. Mulligan of U.S. Army IEWD for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 60*** *on the TSP Request Card. NPO-18654*

Modem Handles Data at 160 Mb/s

The principal advantages are spectral efficiency and power efficiency.

Lewis Research Center, Cleveland, Ohio

A trellis-coded octal-phase-shift-keying modem transmits and receives continuous or bursted digital data for satellite applications. The modem will help to satisfy the increasing demands for communication of high-speed digital data from sources like high-performance computers and high-definition television transmitters, as well as multiplexed signals from slower signal sources. One of the principal advantages of this modem is that it increases the maximum effective bit rate that can be accommodated in a standard 72-MHz-wide commercial satellite-transponder radio channel from 120 Mb/s to 160 Mb/s.

The system is designed to meet the stringent limitations on bandwidth and required power in the presence of adjacent- and co-channel interference. Advanced modulation and coding theory was used to determine the optimal combination of error-correction coding and multilevel modulation techniques that can perform as required. As a result, the trellis-coded modem can handle data with a spectral efficiency of more than 2 (b/s)/Hz with a power efficiency nearly equal to that of conventional satellite communication systems.

At the transmitter, the bit stream from the source is first encoded by use of a

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periodically time-varying, rate-8/9 convolutional or trellis code. The encoded bit stream is converted to a format suitable for an octal-phase-shift-keying modulator, which transmits the original data plus additional code bits at the rate of 180 Mb/s over a channel about 72 MHz wide.

In the receiver, an octal-phase-shift-keying demodulator recovers the carrier and clock signals as well as the encoded data signals. The 180-Mb/s encoded data signals are presented to a rate-8/9 high-speed Viterbi decoder, which outputs the decoded bit stream at the original rate of 160 Mb/s, with errors corrected up to the capacity of the code.

This work was done by James M. Budinger of **Lewis Research Center** *and Susan P. Miller and J. Mark Kappes, David Layer, and Gilmore House of the COMSAT Labs. For further information,* ***write in 88*** *on the TSP Request Card.*
LEW-15288

Hyperswitch Communication Network Computer

The network is designed to support high-level software and expansion of itself.

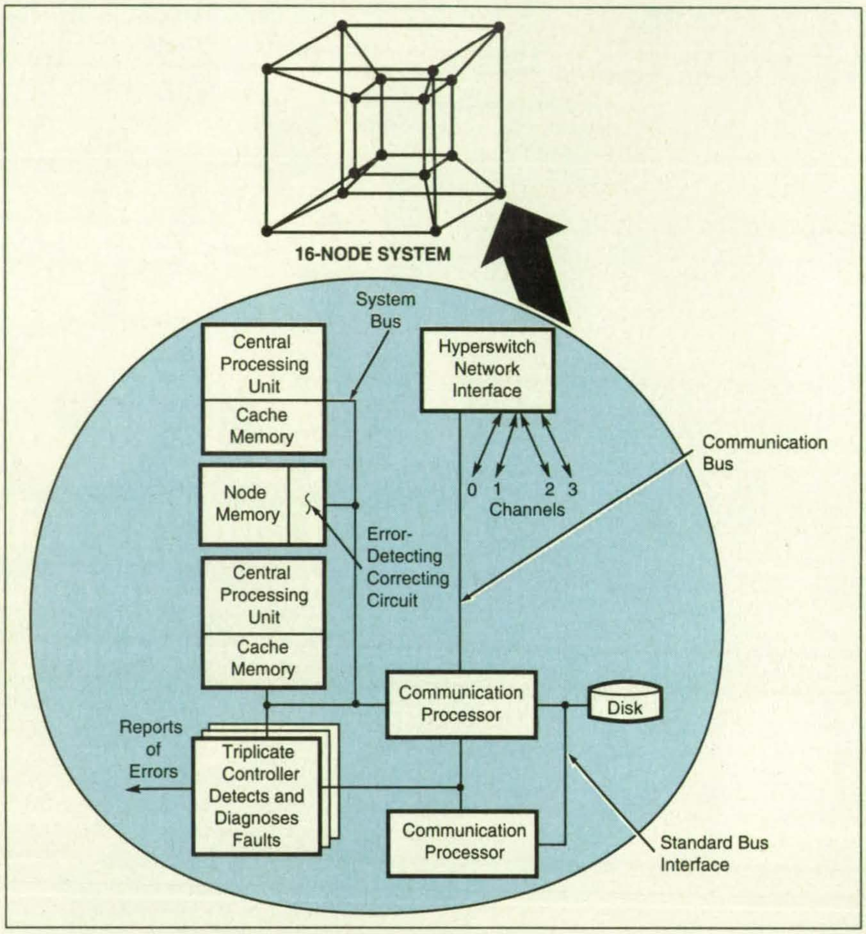
NASA's Jet Propulsion Laboratory, Pasadena, California

The Hyperswitch Communication Network (HCN) computer is a prototype multiple-processor computer that is being developed at NASA's Jet Propulsion Laboratory. The HCN computer is so named because the multiple processors and the communication links between them constitute a network that has a hypercube configuration in the sense that the nodes of the network (the processors) and the links are topologically equivalent to the corners and edges, respectively, of a hypercube (see figure). The HCN computer incorporates an improved version of the hyperswitch communication network described in "Hyperswitch Network for Hypercube Computer" (NPO-16905), *NASA Tech Briefs*, Vol. 13, No. 9 (September, 1989), page 44.

The HCN has been enhanced since the previous description, so that now it supports many higher-level operations and has additional capabilities. The HCN computer is a message-passing, multiple-instruction/multiple-data computer that offers significant advantages over older single-processor and bus-based multiple-processor computers, with respect to price/performance ratio, reliability, availability, and manufacturing. The design of the HCN operating-system software provides a uniquely flexible computing environment that accommodates both parallel and distributed processing. It can also achieve a balance among the following competing factors: performance in processing and communications, ease of use, and tolerance of (and recovery from) faults.

The HCN operating system supports object-oriented concurrent programming in which the computing system to be constructed is represented as a collection of concurrently executable program models called objects. Each object resides on one node or is distributed over several nodes for the sake of performance. This approach to programming exploits parallelism in both the architecture and the application.

The HCN computer can be classified as a supercomputer because the architecture of the HCN extends the applicability of a parallel computer system to supercomputer problems that place heavy demands on the system for high communication bandwidth, low latency, and communication between topologically distant nodes by passing of messages via intervening nodes. Each node contains a custom-designed hyperswitch message-routing processor, which also acts as a buffer and which executes an adaptive, hardware-based routing algorithm that is highly tolerant of faults and provides low message latency. Network support for expansion of the network itself is provided by the design of the hyperswitch message-routing processors and algorithm to implement an interconnection system that modifies its own configuration according to the number of nodes. Thus, the HCN provides low communication overhead, making parallelism potentially attractive in that a programmer who seeks maximum performance would tend to take advantage by partitioning a problem into the finest possible granularity to create the maximum amount of parallelism.



Each Node of the HCN Computer contains two reduced-instruction-set microprocessors, one of which acts as a master central processing unit, the other of which acts as a checker. The node also contains communication and control processors. Although 16 nodes are shown here for simplicity, the prototype network contains 32 nodes.

This work was done by John C. Peterson, Edward T. Chow, Moshe Pniel, and Edwin T. Upchurch of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 83*** *on the TSP Request Card.*
NPO-18588

Measuring Furnace/Sample Heat-Transfer Coefficients

Complicated, inexact calculations are now unnecessary.

Langley Research Center, Hampton, Virginia

The device illustrated in Figure 1 is used to simulate and measure the transfer of heat between a directional-solidification crystal-growth furnace and an ampoule that contains the sample of crystalline material to be grown. The device, called the "HTX," has the size and shape of the ampoule and is put into the furnace in place of the ampoule. It can be used to determine coefficients of transfer of heat between the ampoule and the furnace as functions of temperature, surface emissivity of the sample and/or ampoule, and gas (if any) in the furnace. These coefficients are needed to refine our understanding and control of the crystal-growth process and to improve the quality of the grown crystals.

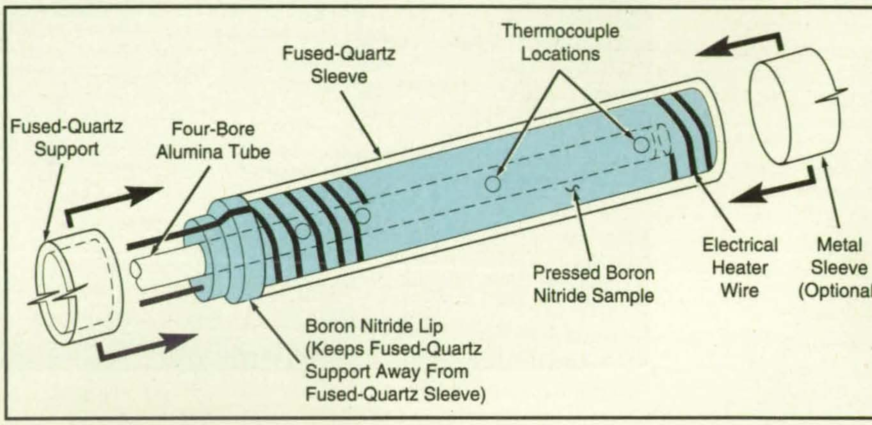


Figure 1. The **HTX** is essentially an instrumented substitute for a crystal-growth-ampoule that contains an electrical heater, thermocouples, and a sample of boron nitride (instead of the crystal-growth material).

Heretofore, these heat-transfer coefficients were not measured, but only estimated by use of nonlinear coupled differential equations with inexact boundary conditions and uncertain thermophysical values. With the HTX, it is not necessary to rely on complicated, uncertain estimates: the HTX yields measurement data that can be used to calculate heat-transfer coefficients directly, without need for assumptions or prior knowledge of the physical properties of the furnace, furnace gas, or specimen.

The HTX includes a fused-quartz sleeve, which matches the crystal-growth ampoule. In place of the crystalline material to be grown, the fused-quartz sleeve is filled mostly with a sample of pressed boron nitride, which is chosen because it is heat-resistant and adequately thermally conductive. An electrical heater wire is wound around the boron nitride sample. A four-bore alumina tube fits into an axial hole in the boron nitride sample and contains four thermocouples that measure the temperatures at four axial locations. Other thermocouples (not shown) measure temperatures in the furnace, outside the ampoule. Sleeves of different metals can be slipped onto the fused-quartz sleeve to change the net emissivity as desired.

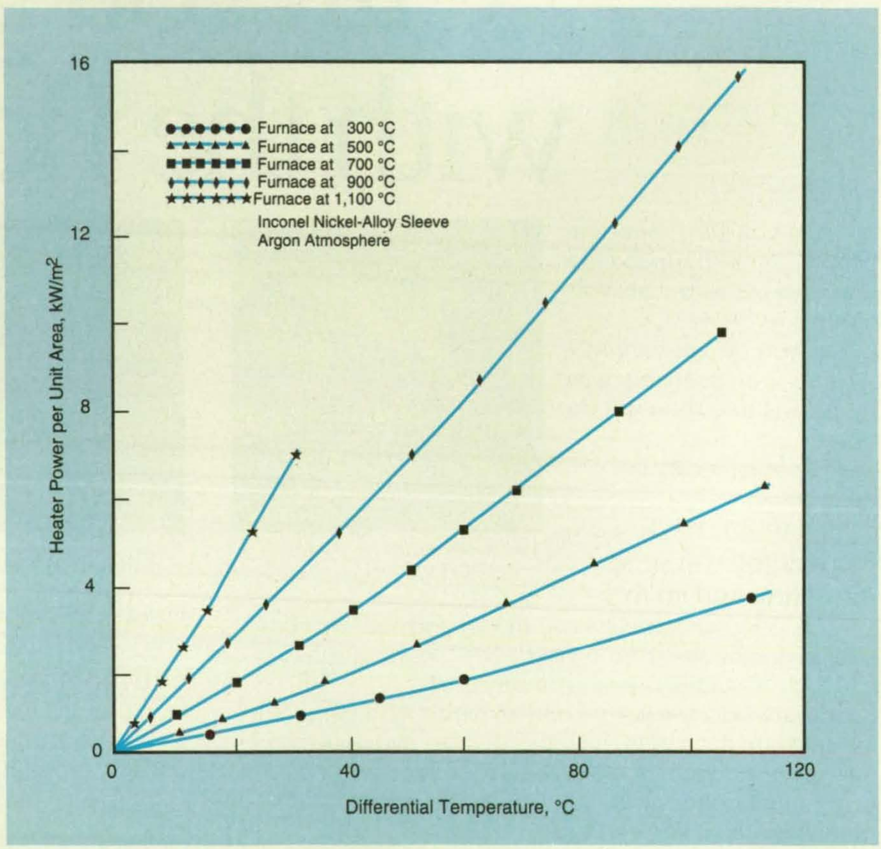


Figure 2. The **HTX Is Heated** until it reaches a known steady temperature above that of the furnace. The heat-transfer coefficient then equals the heater power divided by the differential temperature.

In operation, a known amount of electrical power is supplied to the heater wire, heating the sample above the temperature of the interior of the furnace environment. When the temperature of the sample reaches a steady value, the rate of transfer of heat from the sample to the furnace must equal the heater power. Then the coefficient of transfer of heat between the sample and the furnace is simply equal to the heater power per unit area of the sample divided by the difference between the temperature of the sample and the temperature of the furnace (see Figure 2).

With the HTX, one can determine not only total heat-transfer coefficients but also coefficients of transfer of heat in

different modes. For example, by taking measurements with various atmospheres and with a vacuum, one can investigate the effects of convection. Similarly, by leaving the atmospheres the same but using sleeves of various emissivities, one can investigate the effects of radiation.

This work was done by William R. Rosch of the University of Virginia and Archibald L. Fripp, Jr., William J. Debnam, Jr., and Glenn A. Woodell of **Langley Research Center**. *For further information,* ***write in 66*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 24]. Refer to LAR-14868.

Series-Connected Vapor/Vapor AMTEC Cells

Size and weight would be reduced; operating lifetime would be increased.

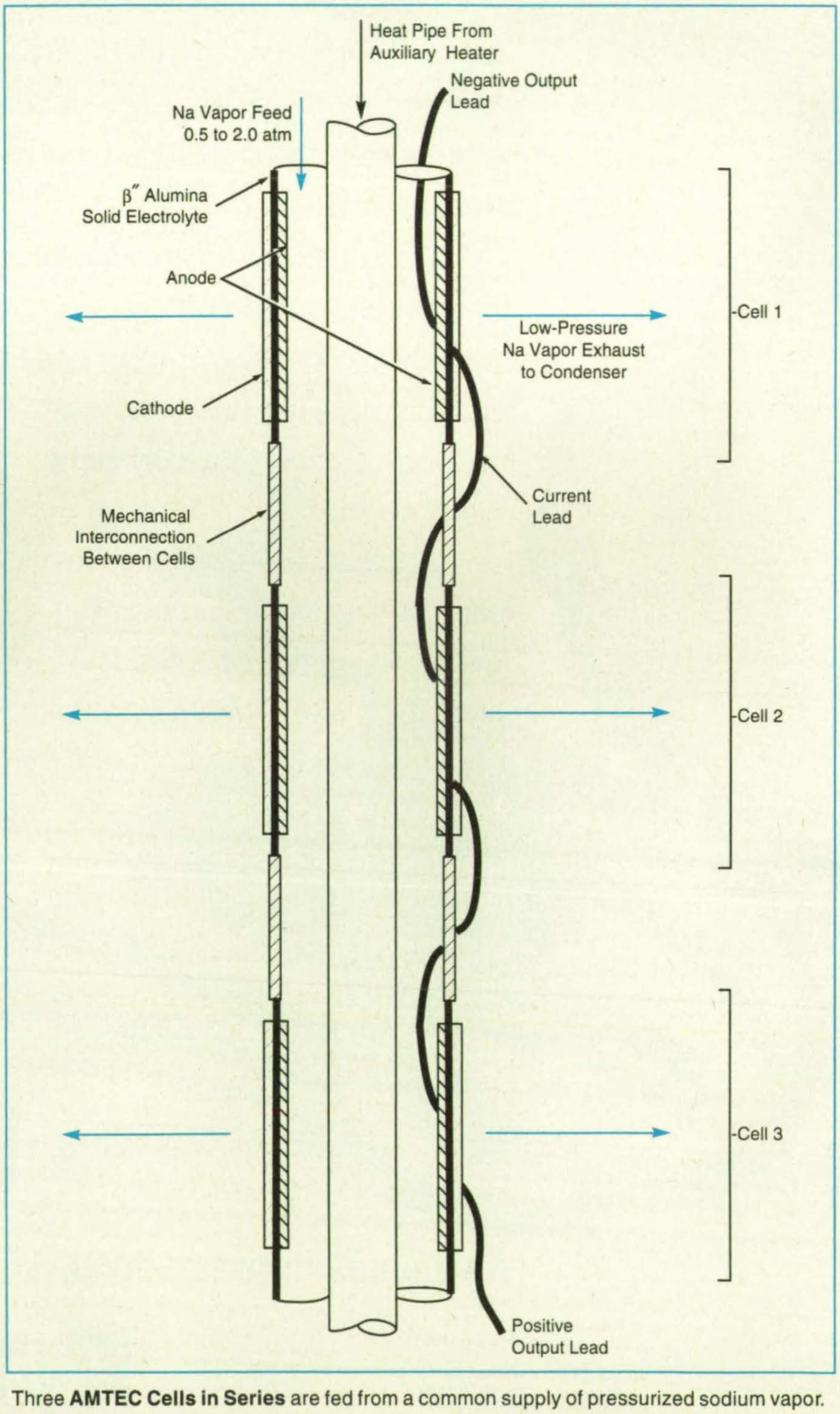
NASA's Jet Propulsion Laboratory, Pasadena, California

The figure illustrates schematically a developmental alkali-metal thermal-to-electric converter (AMTEC) in which the cells are fed from a common supply of high-pressure sodium vapor and are connected electrically in series. Typically, each cell of a conventional AMTEC produces a current of as much as 100 A, but at a potential as low as 0.5 V; therefore, series electrical connection of cells is needed to obtain adequate output voltage. Of course, as an additional benefit of the series connection and increase in voltage, one can reduce the current and, therefore, the size and weight of the conductors.

Unlike in prior AMTEC's fed by vapor and/or liquid sodium, no liquid sodium makes contact with any part of the AMTEC cells: the cells are kept hot enough (by heat from the sodium-vapor feed, possibly assisted by an auxiliary heater) that sodium vapor does not condense to liquid in the cells. Unlike in prior AMTEC's, the anodes of the cells are not composed of liquid sodium. Instead, the sodium vapor is supplied to the solid electrolyte of each cell through a porous metal anode on the upstream side.

The solid electrolyte consists of β″ alumina, which conducts Na^+ ions but not electrons. Electrons that have traveled through the power-consuming circuitry recombine with the Na^+ ions at a porous metal cathode on the downstream side of the solid electrolyte, where the reconstituted Na atoms are emitted as sodium vapor. Even though the cells are connected electrically in series, the vapor can be fed to them in parallel from a common boiler without significant electrical loss because the electrical resistivity of the vapor is very high — greater than 10^{19} Ω•cm with a typical supply temperature of 900 to 1,200 K and supply pressure of 0.5 to 2 atm (0.05 to 0.2 MPa).

The three cells shown in the figure are arranged along a cylinder and supplied with the sodium vapor from an annular space in the cylinder. The cathode of cell 1 is connected to the anode of cell 2, and the cathode of cell 2 is connected to the anode of cell 3; the current leads for these connections could



Three **AMTEC Cells in Series** are fed from a common supply of pressurized sodium vapor.

be simply extensions of the electrode and current-collector substructures.

Series connection of cells as envisioned by some designs requires current-carrying feedthroughs at high temperature. The insulators for these feedthroughs may be subject to chemical attack by hot Na. The resulting electrical shorting of the conductors to the surrounding structures would bypass the cells electrically. The cells would then be unable to contribute power to the network. The proposed design reduces the need for high-temperature feedthroughs in that the cells would be internally connected. The power can be withdrawn through a feedthrough at a lower temperature without significant thermal loss. A feedthrough under these conditions will last much longer and is less likely to limit the life of the cell.

This work was done by Mark L. Underwood, Roger M. Williams, Margaret A. Ryan, Barbara Jeffries-Nakamura, and Dennis O'Connor of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 93*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office–JPL [see page 24]. Refer to NPO-18667.

Single-Heater, Three-Zone Furnace

The temperature profile can be shaped with the help of thermal barriers.

Marshall Space Flight Center, Alabama

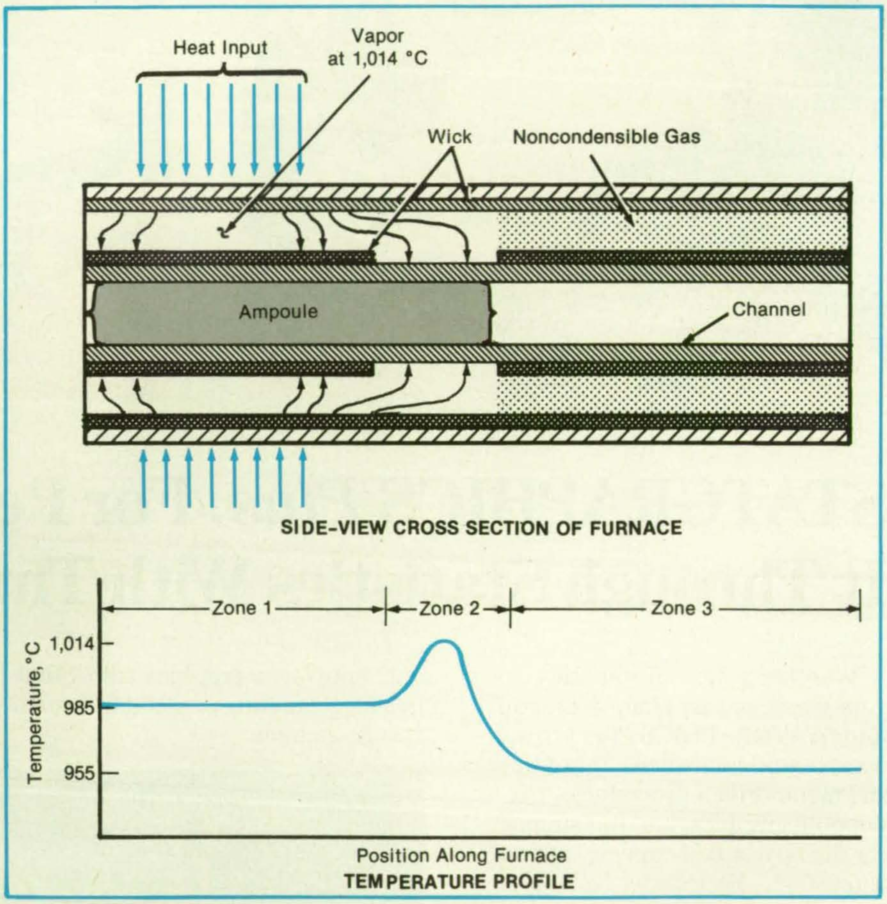
A proposed furnace for use in experiments on the growth of crystals of a highly pure material (e.g., a semiconductor) in an ampoule would provide three temperature zones, yet would contain only one heat-pipe liner and one heater and would operate with only one controller. The furnace would be simple in comparison with present three-zone furnaces, each of which typically includes separate heating and control components for each zone.

An annular heat pipe would surround the channel along which the ampoule would be moved (see figure). The working fluid of the heat pipe would be vaporized in the heat-input region at a temperature slightly above that required for zone 2.

To obtain the temperature required in zone 1, which would be lower than that required in zone 2, the thermal resistance in this part of the heat pipe would be increased by the addition of a wick on the inner cylindrical wall. The thermal resistance in zone 2 would be relatively low, so that the temperature in this zone could approximate that of the vapor.

Zone 3 is required to have the lowest temperature. To lower the temperature to the required value, a wick on the inner cylindrical wall would increase the thermal resistance, and a noncondensible gas would impede the flow of working fluid to the wick.

A variety of three-zone temperature profiles in the furnace could be created by changing the thermal resistances of the zones and injecting a noncondensible gas at an appropriate point. The furnace could thus be used for a variety of experiments.



Three Temperature Zones would be established as thermal resistances of wicks and noncondensible gas reduced the flows of heat into the channel that contained the ampoule. The motion of the ampoule along the channel would cause the gradients of temperature to move along the specimen in the ampoule.

This work was done by Nelson J. Gernert and Robert M. Shauback of Thermacore, Inc. for **Marshall Space Flight Center**. *For further information,* ***write in 27*** *on the TSP Request Card.*

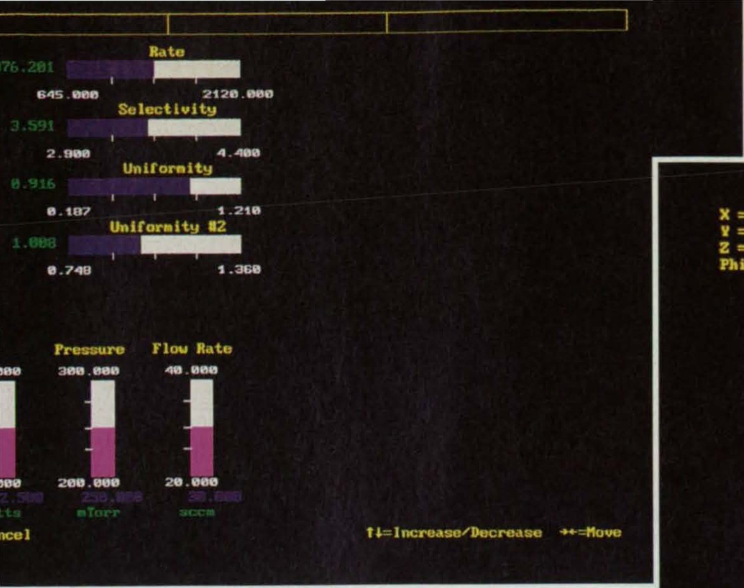
Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 24]. Refer to MFS-26203

Vapor-Exposure Cell for Testing Thin-Film Electrodes

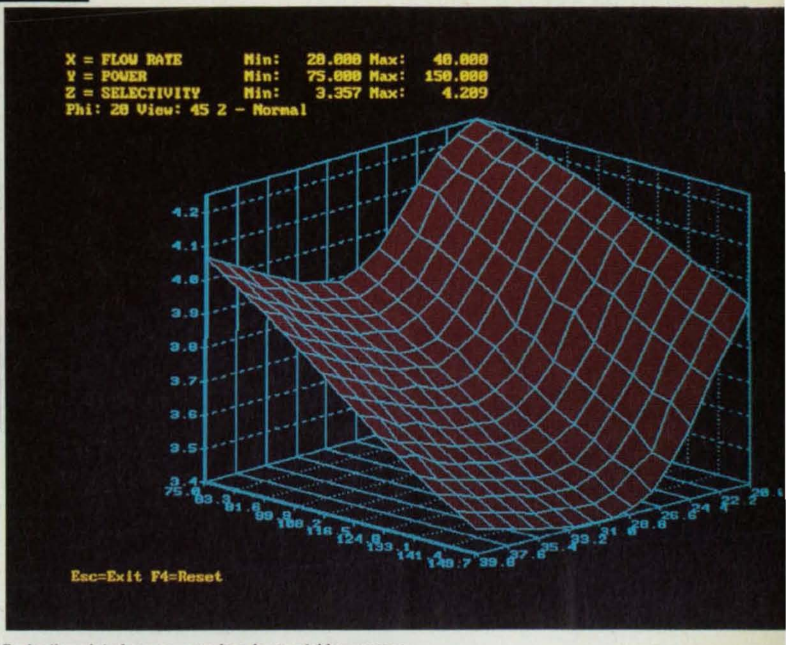
Thin-film electrodes on solid electrolytes can be tested electrochemically at high temperature.

NASA's Jet Propulsion Laboratory, Pasadena, California

A vapor-exposure test cell (VETC) is designed to be used in testing thin-film electrodes on solid electrolytes. The use of the VETC is much simpler and less expensive than is testing an alkali-metal thermal-to-electric converter (AMTEC), fuel cell, electrolysis cell, or other entire device that contains solid electrolyte and electrodes of the material and configu-



Virtual Process Simulator - allows the engineer to interactively simulate a process.



Evaluation plot of response surface for an etching process.

NeuralWorks DANA 3.1

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ration to be characterized.

The VETC includes a stainless-steel cylindrical chamber and is operated in a furnace (see figure). A flange at one end of the chamber provides a feedthrough for a cylindrical heater well that lies on the axis of the chamber, feedthroughs for electrical leads to four electrodes, and two feedthroughs for thermocouples, gas inlets, or other devices. Electrodes are deposited in sets of two, three, or four on a cylinder of solid electrolyte (for example, ß" alumina for an AMTEC-style experiment). The heater well is electrically insulated with a alumina; the solid electrolyte piece with the electrodes is mounted on the heater well.

The feedthroughs are sealed to keep the alkali-metal vapor and/or other test gas in the chamber. Before sealing, solid sodium or other material that is to be evaporated to provide the alkali-metal vapor is put into the chamber. Alternatively, gas or liquid can be bled into the chamber via one of the feedthroughs.

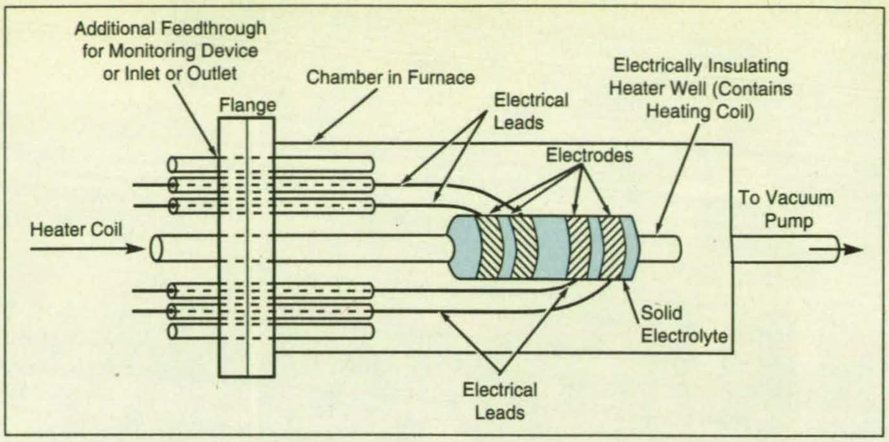
After mounting the sample in the VETC, the entire chamber is placed in a furnace and evacuated at room temperature to remove impurities and water. The chamber can then be heated by use of the furnace and/or the heater well to bring the solid electrolyte and electrodes to operating temperature. The vapor pressure in the cell is controlled by controlling the temperature of the flange if vapor is provided by a charge of sodium or other liquid material inside the cell. Alternatively, the pressure can be controlled by bleeding a known quantity of gas into the cell and/or controlling the evacuation of the cell.

Electrochemical data are taken by operating the sets of electrodes in the manner of a two- or three-electrode cell with a potentiostat. Typically, sets of current-vs.-voltage data taken in tests of a candidate electrode material are compared with corresponding data taken in tests of a well-known material. The current-vs.-voltage data are analyzed to extract performance parameters for comparison. These parameters include exchange current, charge-transfer resistance, coefficient of diffusion of the vapor on the electrode surface, and a morphology factor. In addition, data from electrochemical-impedance-spectroscopy experiments in a four-electrode configuration can be used to analyze conductivity and other properties of the solid electrolyte on which the electrodes are deposited.

A combination of 3 approaches can be taken in analyzing the electrochemical data. In the first approach, one analyzes limiting currents directly to determine both the dimensionless morphology factor and an effective diffusion coefficient for the electrodes. The second approach involves the use of theoretical equations from which one obtains the electrochemical parameters from the slope of the current-vs.-voltage curve through 0 V, under the assumption that the morphology factor can be calculated from the mass-transfer-limited currents. The third approach involves the iterative numerical solution of finite-difference equations of the spatial distribution of electrochemical potentials and electrical and material currents in the electrode and electrolyte structures.

This work was done by Margaret A. Ryan, Roger M. Williams, Barbara Jeffries-Nakamura, Mark L. Underwood, and Dennis O'Connor of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 97*** *on the TSP Request Card. NPO-18620*

NPO-18620



This **Vapor-Exposure Test Cell** enables the realistic testing of thin-film electrodes on solid electrolytes.

Passive Cooling for Large Infrared Telescopes

The telescopes can be cooled to below 20 K without using cryogen.

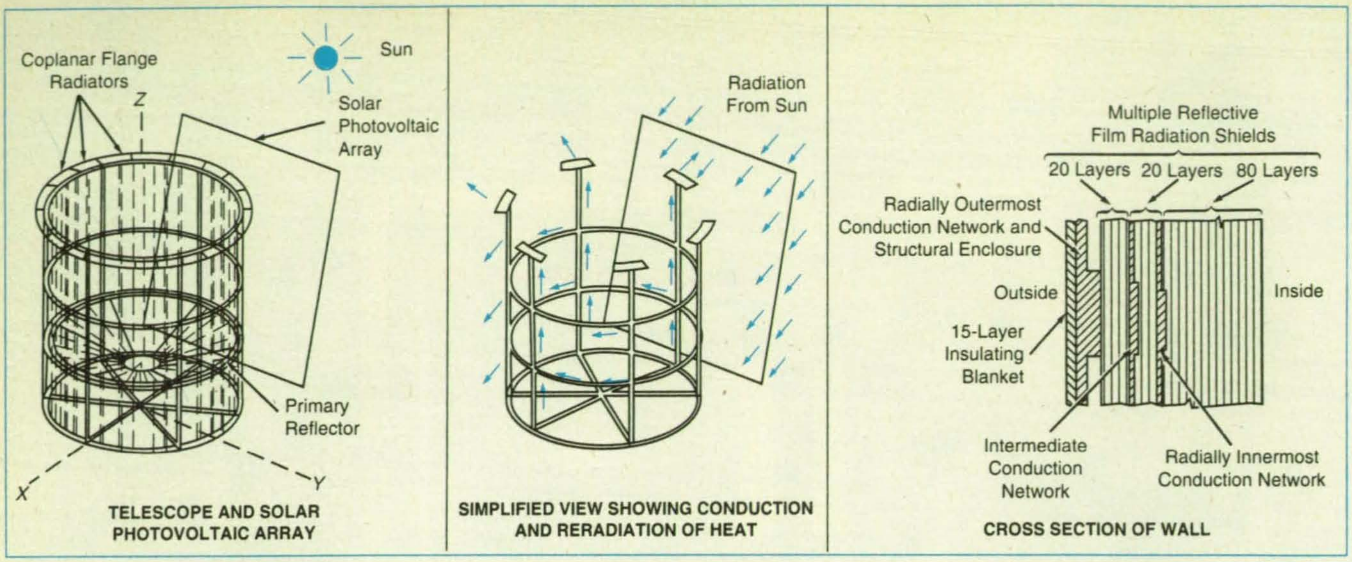
NASA's Jet Propulsion Laboratory, Pasadena, California

A conceptual passive-cooling technique would enable a very large infrared telescope in the vacuum of outer space to be cooled to below 20 K without using cryogen. The telescope would be orbiting the Earth at a high altitude of around 100,000 km. This scheme would also offer a very small gradient of temperature across the primary telescope reflector, so that thermal distortions would be smaller; consequently, the accuracy of the surface figure of the reflector would be significantly enhanced. The passive-cooling technique could also be applied to the building of very large cryostats and to the development of very large sun shields in the traditional manner, and some elements of the technique could be adapted for current small observatories.

As shown in the figure, the primary and secondary telescope reflectors, the detectors, and the associated instruments would be housed in a cylindrical cage 12 m in diameter and 12 m long. The telescope would be considered to consist of this cage and its contents. The warm electronics, antennas, and other service hardware would be located outside and thermally isolated from the telescope. An associated solar photovoltaic array would be positioned to shade the telescope completely, so that the only source of heat visible from the telescope would be the solar photovoltaic array. The large telescope would be assembled in space with modules prefabricated on earth.

The cylindrical cage would consist of three nested concentric conduction networks with multiple reflective film radiation shields placed between them. The conduction networks would be made of 6061 aluminum, and the radiation shields would be made of Kapton (or equivalent) film with aluminum vacuum-deposited on both sides to give an emissivity of 0.03. Eighteen coplanar flange radiators made of 6061 aluminum would fit together into an annulus that would constitute a flange at one end of the cylindrical cage. The thin edges of these radiators would be coated with low-emissivity material and would not contact each other. Low-thermal-conductivity spacers would separate the three conduction networks.

The radially outermost network would be integral with a thin skin that would serve as the structural enclosure. Each



The **Cagelike Cylindrical Housing**, shaded by the solar photovoltaic array, could cool an infrared telescope in a vacuum to below 20 K.

of the 2 gaps between the 3 networks would be filled with 20 layers of separated radiation shields, and 80 layers of separated radiation shields would be placed inward of the radially innermost conduction network. A 15-layer insulation blanket would cover all of the outside of the radially outermost conduction network except for a 120° segment on the side facing away from the Sun. The outer layer of this 15-layer blanket would have an emissivity of 0.03, as would the inner surface of the cylinder below the reflector. The radially inner surface of the cylinder above the primary reflector would be made of aluminized Teflon (or equivalent) with an emissivity of 0.8, and aluminum would be vapor-deposited on both sides of the primary reflector. The other exposed aluminum surfaces (including the flange radiators and the 120° portion of the outer cylindrical surface facing away from the Sun) would be painted with zinc orthotitanate, which would have an end-of-life emissivity of 0.91. Thermal analysis by computer simulation shows that this design could result in temperatures below 20 K at the reflector.

This work was done by Edward I. Lin of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 25*** *on the TSP Request Card.* *NPO-18704*

Instrumented Pneumatic-Impact Tester

Light emitted by ignition of a specimen can be measured.

Lyndon B. Johnson Space Center, Houston, Texas

The device shown in simplified form in Figure 1 is designed to test the susceptibility of a polymeric material to ignition by "pneumatic impact" in high-pressure gaseous oxygen; that is, the ignition that results from a sudden increase in the pressure of oxygen. The device can be used to determine differences among the susceptibilities to ignition of different materials and of different batches of nominally the same material proposed for use in systems that contain pressurized oxygen. The device can also be used to show characteristics of ignition and combustion. Although tests of susceptibility to ignition by pneumatic impact have been performed before to screen polymeric materials, the results obtained by use of prior test equipment have not been sufficiently reproducible to distinguish clearly among different materials and different batches of nominally the same material.

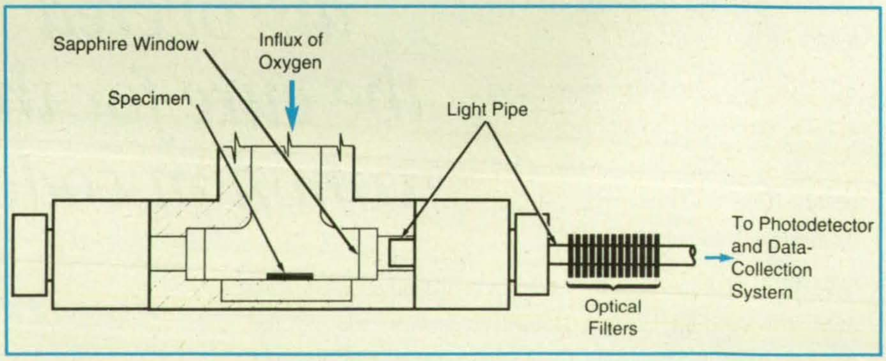


Figure 1. The **Pneumatic-Impact Tester** is essentially a small pressure chamber equipped with a specimen holder and an optical port.

In the device of Figure 1, light from ignition passes through a sapphire window and via a light pipe to a photodetector and a fast data-collection system, which records the intensity of the light as a function of time. Simultaneously, the system records the pressure of oxygen as a function of time. The pressure history is kept nearly the same from one specimen to another in the following sense: By setting a final pressure and regulating the flow of oxygen with a control valve, the pressure on the specimen can be made to reach the specified test pressure in the specified test time.

Figure 2 shows the light-intensity and pressure curves obtained in tests of low-density polyethylene tape, clean polytetrafluoroethylene tape, and polytetrafluoroethylene tapes contaminated with 5 and with 15 mg of oil, respectively. (To eliminate differences attributable to surface finish as much as possible, the three polytetrafluoroethylene tapes were taken from the same roll.) The curves generated in this and in other tests of this type are analyzed to determine peak-initiation times, shapes and heights of peaks, and shapes of tails. In this case, these features indicate distinctions between con-

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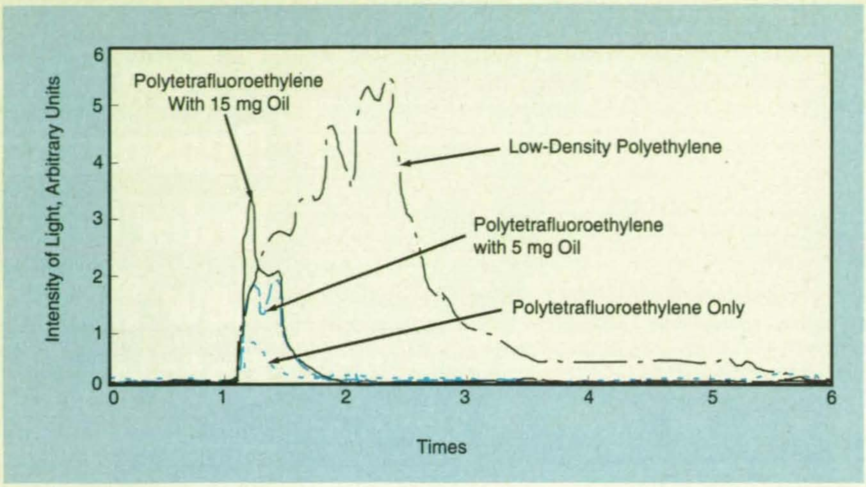


Figure 2. These **Light-Emission Curves** were obtained in pneumatic-impact tests of the indicated materials.

taminated and uncontaminated polytetrafluoroethylene tapes and between the polytetrafluoroethylene and the polyethylene tapes.

This work was done by Richard M. Shelley and Norman Armendariz of Lockheed Engineering & Sciences Co. for **Johnson Space Center**. *For further information,* ***write in 51*** *on the TSP Request Card. MSC-21893*

Moving-Temperature-Gradient Heat-Pipe Furnace Element

In comparison with prior crystal-growing apparatuses, this one is simpler, smaller, and more efficient.

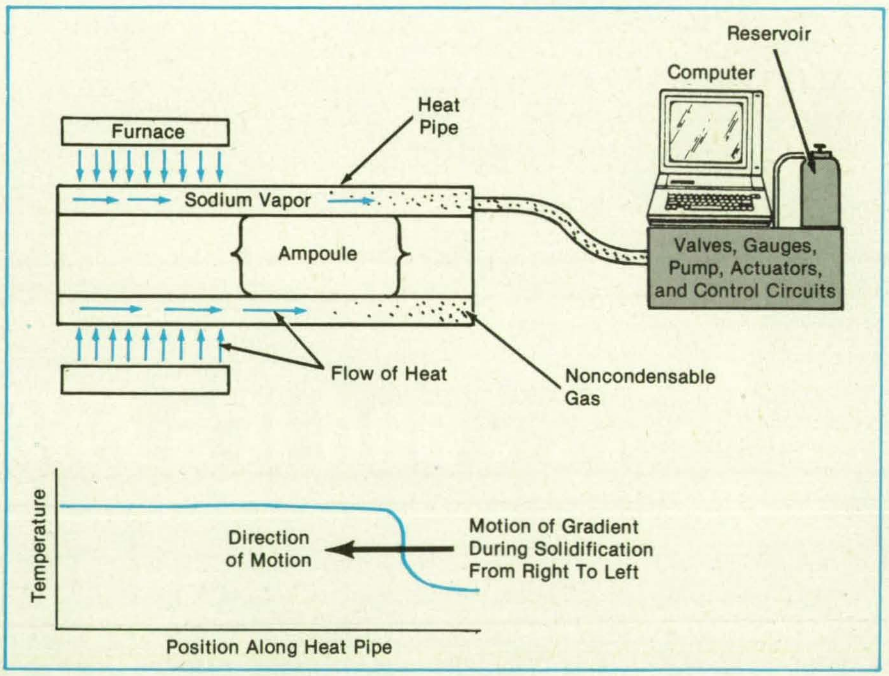
Marshall Space Flight Center, Alabama

The figure illustrates an improved apparatus for growing crystals by the Bridgman (directional-solidification) method, in which a temperature-gradient solidification front is moved through a molten material. Heretofore, translation of temperature gradients in directional-solidification apparatuses was achieved by use of multiple temperature zone furnaces and ampoules of material that were translated relative to each other by motor-driven mechanisms. The improved apparatus can be simpler and shorter than the prior apparatuses because it does not contain multiple separately controlled heating and cooling zones and because there is no translation of the furnace and ampoule during operation.

In the improved apparatus, the ampoule of material to be directionally solidified is mounted in the central hole of an annular heat pipe, at a suitable axial position between the heated and cooled ends. The heated end is held in a fixed position in a single-element furnace; the other end can be left in ambient air or else actively cooled.

The annular space of the heat pipe contains a condensable working fluid (e.g., sodium) plus a noncondensable gas. The condensation front and the associated temperature gradient can be moved toward the heated or cooled end by increasing or decreasing the pressure of the noncondensable gas. Because of the heat-pipe action on the hot side of the condensation front, the entire hot zone can be maintained at or near the closely controlled temperature of the furnace.

The noncondensable gas is supplied from a reservoir. The pressure of the gas in the heat pipe is controlled by a subsystem of valves, gauges, and a vacuum pump under computer control. (The vacuum pump draws the gas from the heat pipe back into the reservoir when it is required to move the solidification front from the heated toward the cooled end.)



The **Gradient of Temperature** is made to move along the heat pipe by changing the pressure of the noncondensable gas.

Because there is no translation of the ampoule or furnace during the solidification process, there is no need to ensure the ability of the ampoule to slide easily inside the heat pipe. Therefore, it is permissible to have a close fit between the ampoule and the inner wall of the heat pipe: a close fit enhances thermal coupling between the heat pipe and the ampoule and thereby also reduces the undesired thermal influence of uncontrolled heating and cooling through the ends of the ampoule. Also, because there is no translation, insulation can be added to both ends of the ampoule, with consequent reduction in the consumption of power.

This work was done by Donald C. Gillies and Sandor L. Lehoczky of **Marshall Space Flight Center** *and Nelson J. Gernert of Thermacore, Inc. For further information,* ***write in 61*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 24]. Refer to MFS-26205

Modeling Thermodynamics of Charring of a Polymer

Char- and erosion-density profiles from tomography are correlated with other data and with theory.

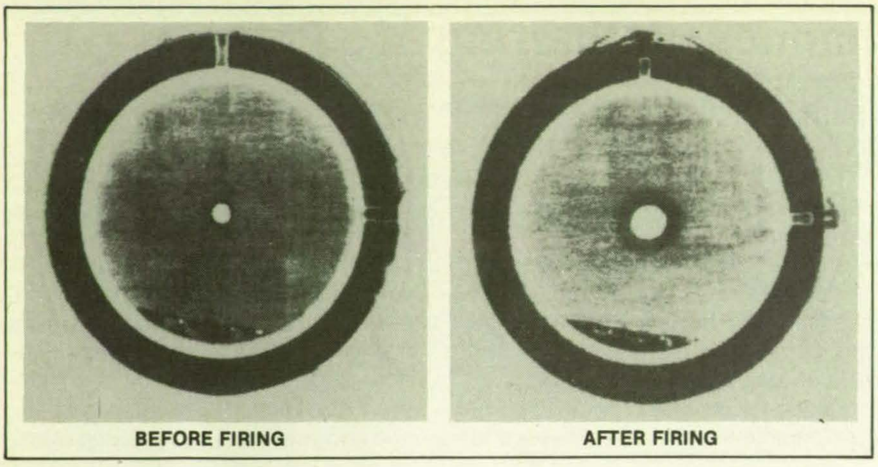
Marshall Space Flight Center, Alabama

An improved method of predicting and of nondestructively analyzing pyrolytic effects in, and thermomechanical properties of, polymers combines theories and techniques from several engineering and scientific disciplines. The method has evolved in an effort to understand the charring and erosion of carbon phenolic ablative material in the nozzle of a rocket engine. The method should also be applicable to other polymers and particularly to the nondestructive engineering analysis of specimens that have been heated, charred, or burned.

The method involves correlations among (1) computed tomographic images of polymer specimens, (2) the spatial distributions of physical and chemical properties in the specimens, and (3) the physical and chemical mechanisms of pyrolysis. The method is based partly on a study of more than 1,000 char- and erosion-density profiles obtained from computed tomographic images of a rocket-nozzle specimen (see figure). It was found in the study that the behavior of a thermally excited polymer material agrees with that expected on the basis of modern nonequilibrium statistical mechanics, polymer statistics, and critical-phase-transition theories. In contrast with prior methods based on classical thermodynamics, this method incorporates these modern theories.

The complexity of the method and lack of space for this article preclude a complete explanation, but the following partial description conveys some of the essence of the method. The first of three main parts of the method is the quantification of the computed tomographic and other available information obtained in nondestructive tests. The computed tomographic image data pertaining to a given specimen are processed into a reduced or averaged set of data and entered into a data base along with other available information to establish correlations with the other available information. For example, surface-recession depths, primary-char depths, and decomposition zones based on tomographic information are compared with measurements of slice specimens, microscopy, and finite-difference predictions to determine the accuracy of data obtained from computed tomography in comparison with that of the data obtained by other methods.

In addition, density differentials with respect to position obtained from computed tomographic data are compared with data from thermogravimetric analysis, which data represent density differentials with respect to temperature: the correlations between these two sets of data are perhaps the most important because they provide temperature parameters, which are needed for further evaluations. The computed tomographic data provide a relationship between change in density and position, whereas the thermogravimetric data provide a relationship between the change in density and temperature. The combined information then provides a relationship between temperature and position. Then applying classi-



These **Computed Tomographic Images** of a cross section of a carbon phenolic rocket-engine nozzle give information on the physical and chemical changes that occurred in the nozzle during firing.

cal thermodynamics, the coefficients of temperature, change in volume, and the change in the number of molecules of each chemical constituent can be extracted from the data base.

The second main part of the method is the development of analytical capabilities — particularly of mathematical models to represent the computed tomographic data and to depict the density of the specimen as a function of position. The third main part of the method is the use of these models to evaluate the properties of the specimen while modeling the thermodynamic response of the specimen by applying irreversible-macroscopic-thermodynamic, linear-response theories and bulk-polymer statistical field theories.

In the development of these parts of the method, results of computations were compared with those of current theories and mathematical models of polymers to establish the feasibility of extracting such essential features and relationships obtainable from the computed tomographic information as phase-transition rates, susceptibility properties, and cracking-length correlations. In particular, the importance of incorporating the statistics of polymers into the thermodynamical model was recognized and addressed as a means of providing a model mechanism for outgassing via propagation of internal cracks and a mechanism for initiating degradation of the polymer by random scission. These two points introduce a consideration of causality into the thermodynamical model; that is, outgassing cannot occur until a crack has provided a path along which gases can escape.

This work was done by Gregory V. Funaro of Martin Marietta Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 57*** *on the TSP Request Card. MFS-28710*

Scanning Tunneling Microscope for Use in Vacuum

Notable features include compactness and low outgassing.

Lewis Research Center, Cleveland, Ohio

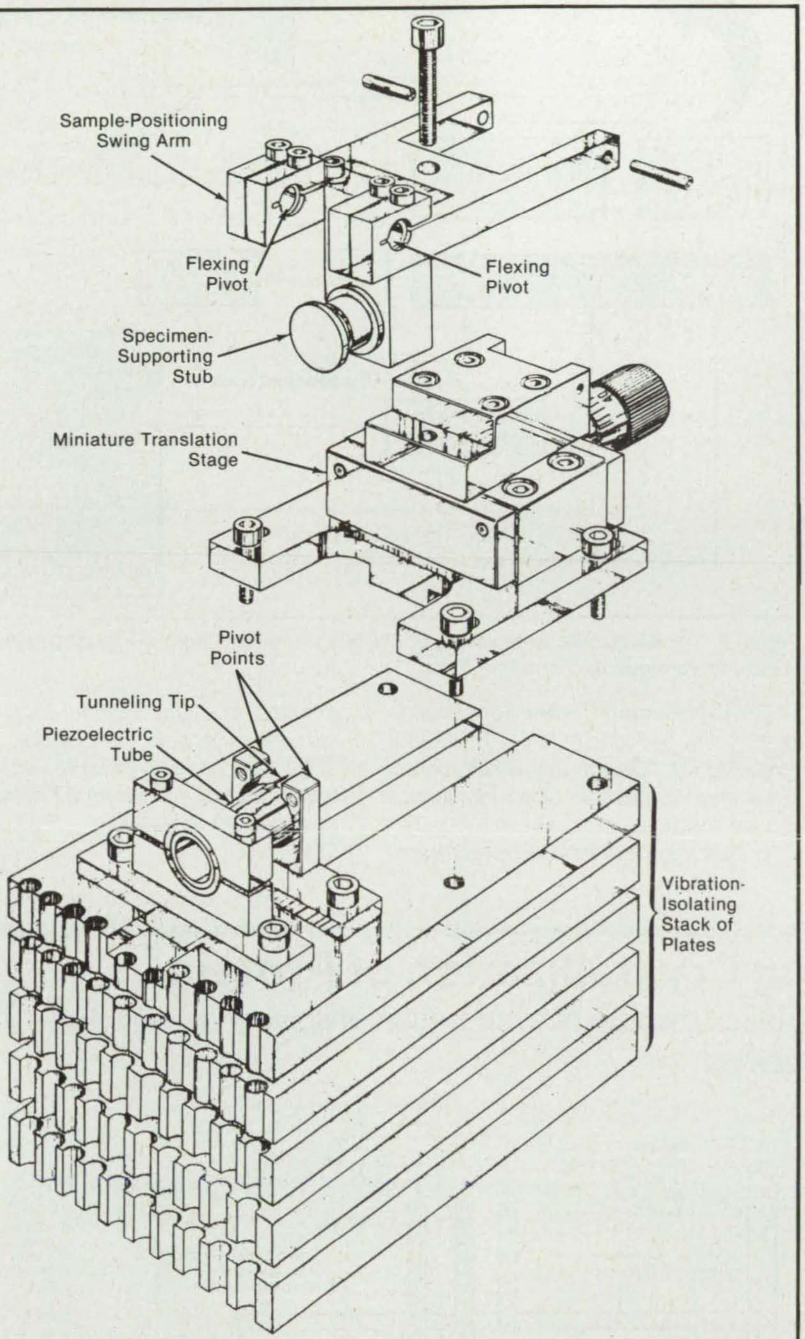


Figure 1. The **Scanning Head** is an assembly of small, mostly rigid components made of low-outgassing materials.

This scanning tunneling microscope is one in a series of such instruments with subangstrom resolution that have been developed in recent years to study surface structures. Although this particular instrument can be used in air, it is designed especially for use in vacuum. For this purpose, the scanning head is made unusually compact, with major components of stainless steel, ceramics, and other low-outgassing materials.

The scanning head (see Figure 1) includes a coarse-positioning mechanical-translation stage, on which the specimen is mounted by use of a standard mounting stub. The tunneling tip — a tungsten wire electrochemically etched to a sharp point — is mounted on a piezoelectric fine-positioning tube. The application of suitable voltages to the electrodes on the piezoelec-

tric tube controls the scan of the tunneling tip across the surface of the specimen.

The scanning head is thermally stable. Temperature gradients are reduced by miniaturizing components and minimizing differences of thermal expansion. High rates of data collection minimize thermal drift that can occur as a function of time.

The mechanical design incorporates several features to minimize the effect of vibrations. One is the use of small, stiff components. Another is to support the scanning head with vibration-isolating plates. The scanning head is surrounded with sound-deadening foam during air testing. The entire assembly is suspended on elastic cords for additional isolation from low frequency vibrations.

The electronic subsystem (see Figure 2) generates the raster voltages for surface scanning of the specimen (*x* and *y* directions), controls the distance between the tunneling tip and the scanned surface, and collects the scan data.

To minimize stray electromagnetic pickup, the first stage of electronic buffering is brought as close as possible to the tunneling tip. An amplifier acts as a voltage follower, buffering the tip potential to externally mounted circuitry. In proper operation, the tip potential is kept very closely to 0 V. The next stage of amplification eliminates steady-state error of the tip voltage and provides control over time constants. The output of a boxcar averager controls the output voltage. A passive voltage divider sets the overall gain of the feedback control loop.

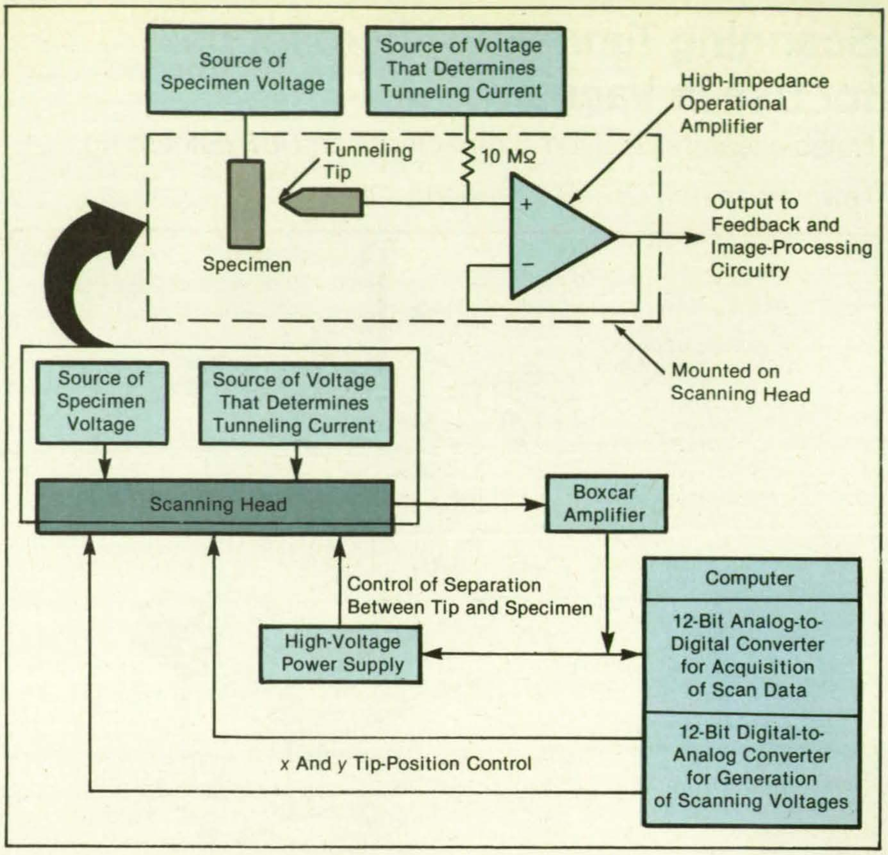


Figure 2. The **Electronic Subsystem** of the scanning tunneling microscope generates scanning voltages and collects data.

This work was done by Phillip B. Abel of **Lewis Research Center**. *Further information may be found in NASA TM-102514 [N90-20353], "Design and Calibration of a Vacuum Compatible Scanning Tunneling Microscope."*

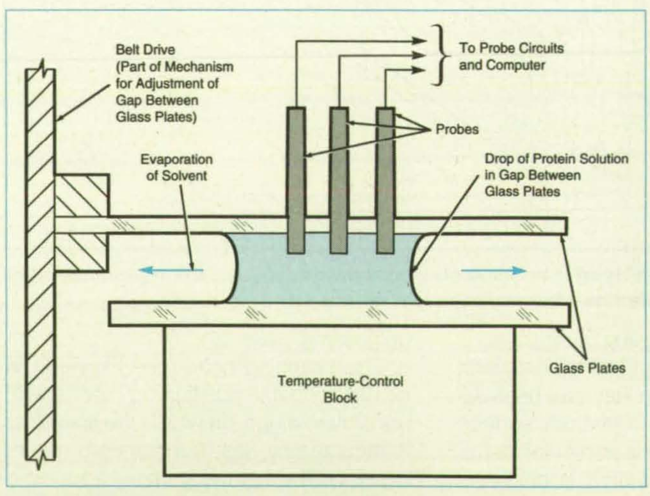
Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LEW-15190

Device for Controlling Crystallization of Protein

The exposed area is adjusted to adjust the rate of evaporation of solvent.

Marshall Space Flight Center, Alabama

The variable sandwich spacer is a device in which protein crystals can be grown at a dynamically controlled rate. The variable sandwich space, includes two closely spaced parallel glass plates, the gap between which can be adjusted precisely. A drop of the solution from which the protein is to be crystallized is placed between the plates, and the drop forms itself into a round volume (see figure). The rate of evaporation of the solvent (which is typically water) and, thereby, the rate of crystallization, can be varied by adjusting the gap between the plates to vary the exposed surface area of the solution. The device is enclosed in an insulated box that protects it against changes in room temperature (±4 °C). The humidity inside the box is fixed by use of a single desiccant bag with no active feedback.



The **Variable Sandwich Spacer** enables the optimization of the evaporative driving force that governs the crystallization of a protein from solution.

By use of this device, one can, for example, initially cause the rate of evaporation to be great enough to maintain high supersaturation of protein to initiate nucleation, and then slow evaporation to avoid multiple nucleations, which can compete with the desired growth of a few,

high-quality protein crystals. Probes for monitoring the pH, concentration of salt, and electrical conductance are easily incorporated into the device through small ports on the plates. These probes yield independent measurements indicative of evaporative loss, and these measurements can be used to adjust the gap between the plates to obtain the desired rate of evaporation or crystallization as a function of time.

The variable sandwich spacer is mechanically more rigid than are the hanging-drop and sitting-drop devices that are also used to crystallize proteins. In the variable sandwich spacer, large oscillations and dislodgment of the drop of solution in response to vibrations are suppressed by the glass plates.

Other advantages of the variable sandwich spacer include the following:

- It is suitable for automated delivery, stable handling, and programmable evaporation of the protein solution.
- Its controlled configuration enables simple and accurate determination of the volume of the solution without disrupting crystallization.
- The pH and the concentration of the precipitant can be controlled dynamically because the pH and the concentration are coupled to the rate of evaporation, which is controllable via adjustment of the gap between the plates.
- It enables variation of the ratio between the surface area and the volume of protein solution. This is an advantage, for example, in the crystallization of a membrane protein, which tends to orient relative to the surface of the solution.

There is favorable viewing between its two transparent plates; aberration caused by curvature of the drop is reduced.

In an alternative version of the variable sandwich spacer, the plates are oriented vertically instead of horizontally as shown in the figure. Vertical plates offer the advantage that as heavy crystals settle in the liquid, they avoid contact with the solid surfaces of the glass plates and hence encounter fewer sites at which secondary crystallization nuclei could form. The vertical plates could be rotated about a horizontal axis to achieve semi-containerless processing.

This work was done by David A. Noever of **Marshall Space Flight Center**. *For further information,* ***write in 85*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 24]. Refer to MFS-28688.

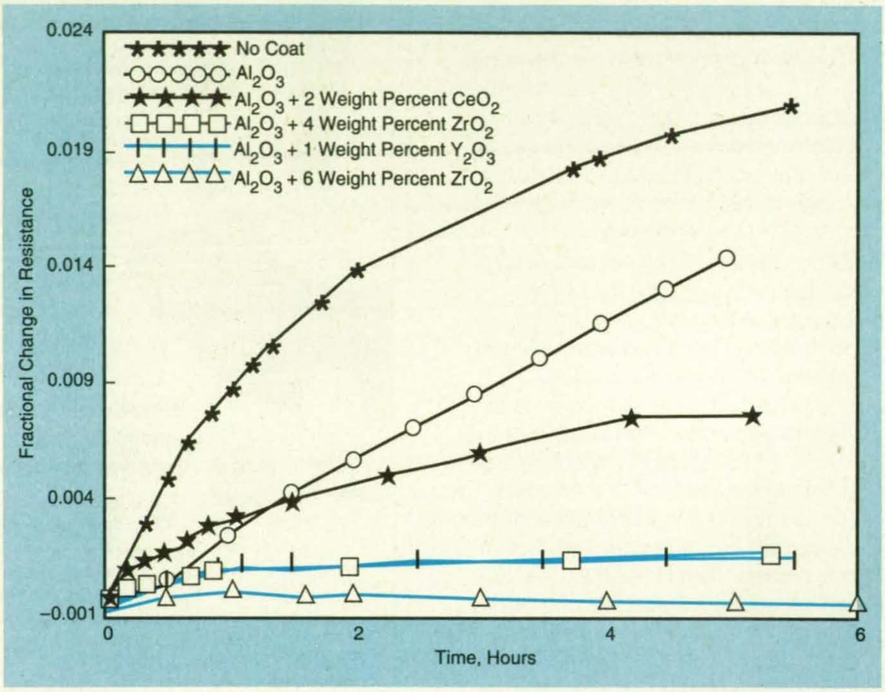
Protective Coats for High-Temperature Strain Gauges

Rare-earth oxide additives in alumina reduce oxidation.

Lewis Research Center, Cleveland, Ohio

The addition of some rare-earth oxides to the prior alumina (only) coating material increases the maximum service temperture of palladium/chromium-wire strain gauges. Previously limited to use a at temperatures below 400 °C, the Pd/Cr wires can now be used at temperatures up to 800 °C without excessive drift in electrical resistance.

The oxides used are zirconia (ZrO_2), yttria (Y_2O_3), ceria (CeO_2), and hafnia (HfO_2). The effect of the addition of one of these oxides to the alumina coat is to decrease the oxidation of the wire at high temperature. The protection against oxidation increases with the concentration of the rare-earth oxide, up to a limiting concentration of 6 percent ZrO_2, 1 percent Y_2O_3, 2 percent CeO_2, or 1 percent HfO_2. Above these concentrations, the rare-earth oxides can react with the Pd/Cr wire. As shown in the figure, the addition of ZrO_2 at 4 to 6 weight percent or Y_2O_3 at 1 weight percent results in the smallest drift in electrical resistance.



Small Amounts of Rare-Earth Oxides in a protective coat reduce the change in electrical resistance of a P/Cr wire 25 µm in diameter at a temperature of 800 °C. Y_2O_3 at 1 weight percent or ZrO_2 at 4 to 6 weight percent yield the lowest change in resistance and were selected for use in protective coats on Pd/Cr-wire strain gauges.

To begin the process of mounting a strain gauge, a coat of Ni/Cr/Al alloy 25 to 50 µm thick is flame-sprayed onto the surface of the strain specimen. Next, an alumina coat 25 to 50 µm thick is applied by flame spraying. The wire strain gauge is then laid on the alumina-coated surface, and a protective coat of alumina containing zirconia or yttria is flame-sprayed over the wire grid and surrounding area to a thickness of 100 to 200 µm.

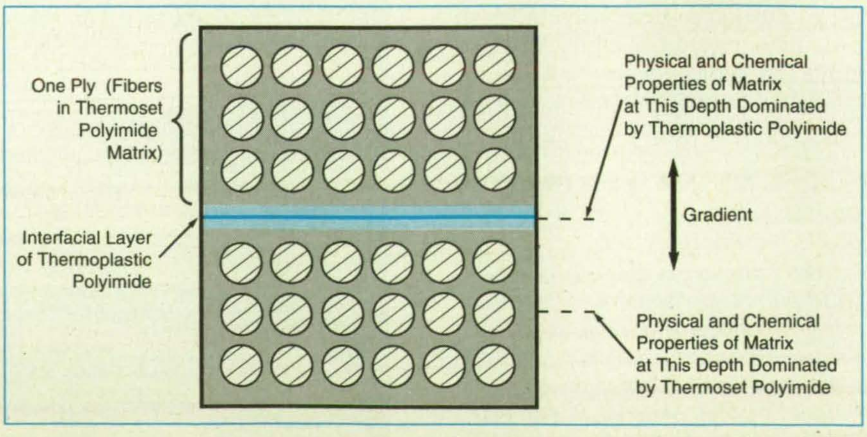
This work was done by Jih-Fen Lei of Sverdrup Technology, Inc., for **Lewis Research Center**. *For further information,* ***write in 41*** *on the TSP Request Card. LEW-15197*

Toughened High-Temperature Thermoset Composites

Thermoset-matrix/fiber laminates are toughened by interlaminar thermoplastic layers.

Langley Research Center, Hampton, Virginia

Laminated composites of carbon fibers and either PMR-15 or LARC™ RP-46 polyimides (these polyimides are thermosetting) can be toughened selectively by incorporating thin layers of Matrimid™ 5218 thermoplastic polyimide at the interfaces between the plies to form gradient semi-interpenetrating microstructures (see figure). The toughening of the composites is accompanied by acceptably small decreases in strength and stiffness. Thick laminates of the toughened composites can be fabricated easily at 500 psi (3.45 MPa). These materials are expected to be useful, for example, in components of aircraft engines, where they could be exposed to high temperatures for short times.



The **Thermoset and Thermoplastic Polyimides** form a single phase, with a gradient between them at the interface between plies.

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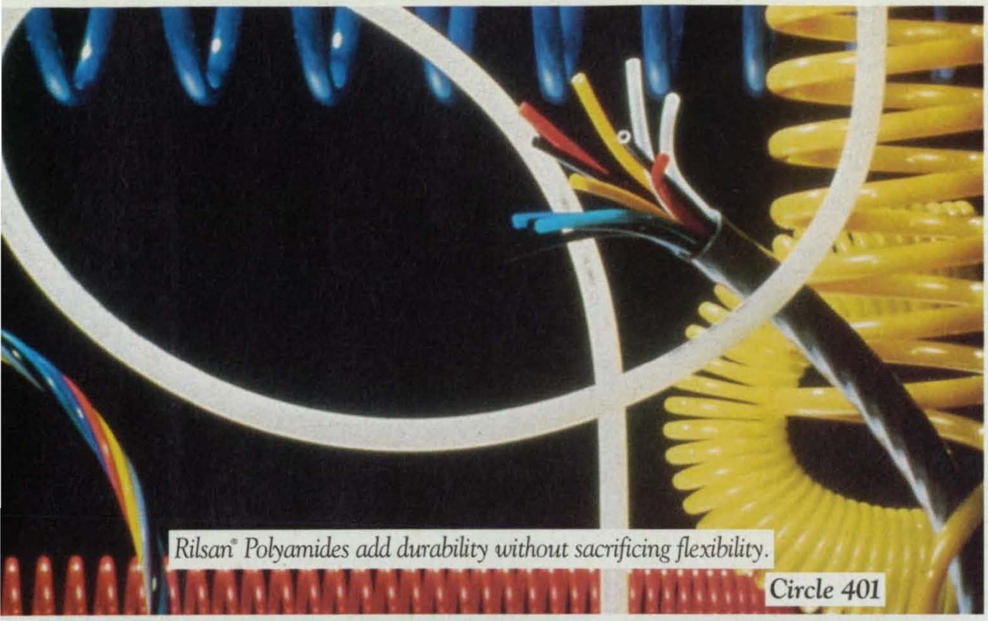

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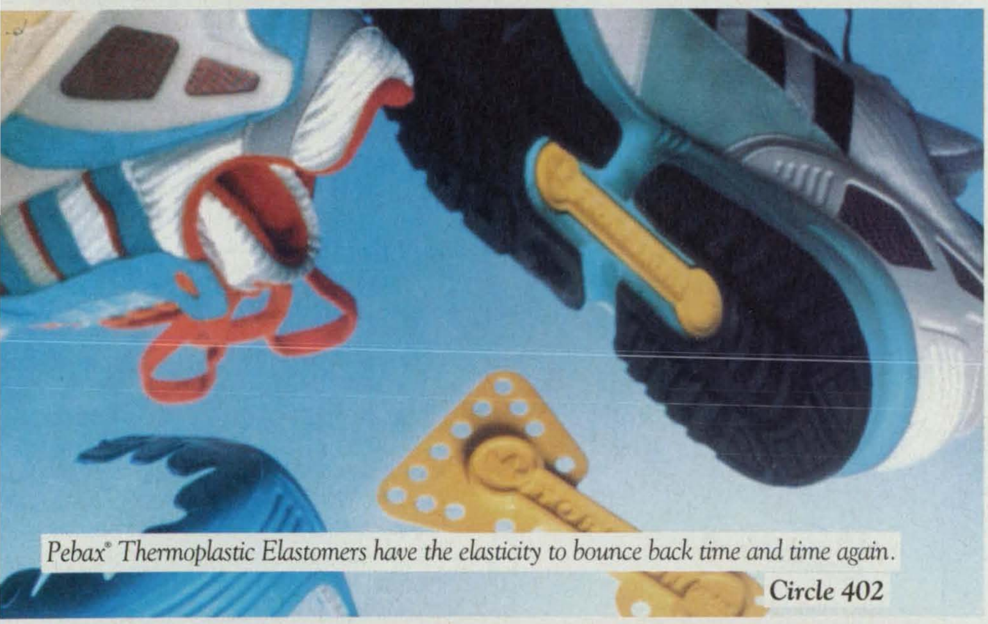

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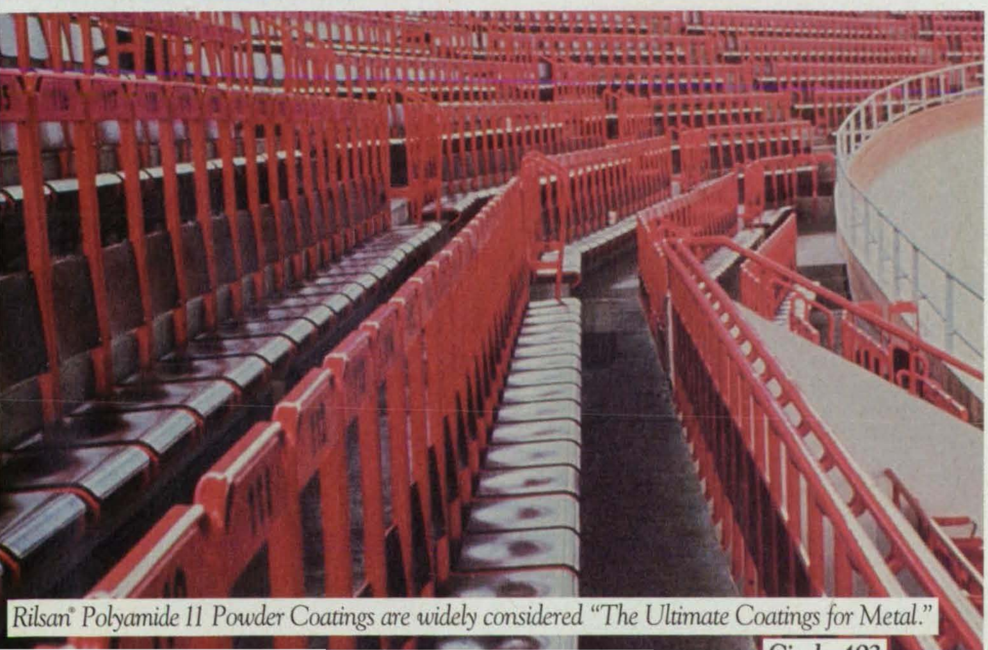

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In experiments, lamina prepregs were made by coating carbon-fiber tows with methanol solutions containing the thermosetting polyimide resins. (The resin, fiber, and solvent contents were adjusted so that the eventual total resin contents of the cured composites would be 40 volume percent.) While the prepregs were still wet with methanol, the prepregs were coated with the thermoplastic polyimide resin in powder form, amounting to 12 weight percent of the total resin content. The prepregs were allowed to dry (by evaporation of the methanol) for several hours, then placed in an air oven, where they were B-staged at a temperature of 200 °C for 1 hour. (By "B-staged," it is meant that they were heated to remove the remaining methanol and to initiate, but not complete, the chemical reactions for conversion of the resins to the imidized uncrosslinked prepolymers.)

The prepregs were cut and stacked into laminates. The laminates were then cured by heating them in a press, using a modified curing cycle that involved temperatures greater and times shorter than those used previously to cure PMR-type polyimides. This cure lasted about 6 hours, and the maximum temperature was 334 °C, whereas the previous lower-temperature cure included a 16-hour postcure at 316 °C. Approximately 50 laminates of different thicknesses and layups were manufactured with fiber volume fractions of 60±2 percent and a void content of approximately 1 percent for a comprehensive study of the engineering properties of four key composite systems.

Apparently, the inherent flexibility of the ether link in 3,4′-ODA imparted better flow characteristics and moderately higher toughness to RP-46 composites relative to PMR-15 composites. This increased toughness was obtained at no sacrifice in engineering strength or stiffness.

Examination of cured specimens showed that the thermoplastic polyimide powder had coalesced and reacted during lamination to yield void-free resin layers at the interfaces between plies. The fractured surfaces of the composite test specimens showed that the thermoplastic and thermoset resins in each composite had coalesced into a single-phase material, with no evidence of films or other phases at the interfaces. There was evidence of strong adhesion between the matrices and fibers. Thermomechanical spectra of the toughened laminates exhibited only single transitions, reflective of single-phase matrices. No appreciable changes in weight were noted in attempts to leach the thermoplastic polyimide from the cured composites by use of solvents known to dissolve the thermoplastic polyimide.

From the foregoing observations, the emerging morphological picture of the

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toughened composites is that of a gradient single-phase semi-interpenetrating form illustrated in the figure. Such a microstructure is likely to provide not only increased toughness and resistance to solvents but also better fatigue endurance and resistance to creep, because of enhanced physical cross-linking arising from entanglement of molecules. By incorporating the toughening material at the most desired location and by providing the cross-linked semi-interpenetrating microstructure, one avoids having to toughen the bulk resin and thereby avoids the attendant increase in cost and difficulty of processing.

This work was done by Norman J. Johnston and Ruth H. Pater of **Langley Research Center** *and Krishna Srinivasan of Old Dominion University. For further information,* ***write in 30*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 24]. Refer to LAR-14885.

Imide/Arylene Ether Copolymers Containing Phosphine Oxide

Phosphine oxide groups react with oxygen to form protective phosphate surface layers.

Langley Research Center, Hampton, Virginia

A series of imide/arylene ether block copolymers that contain phosphine oxide units in the backbone have been synthesized and characterized. In comparison with a commercial polyimide, these copolymers display much better resistance to etching by oxygen plasma: this is because the phosphine oxide units react with atomic oxygen to form a phosphate layer at the surface of the copolymer, thereby protecting the underlying copolymer. The tensile strengths and tensile moduli of these copolymers are also significantly greater than those of a polyarylene ether homopolymer. This unique combination of properties makes these copolymers attractive for films, coatings, adhesives, and composite matrices where resistance to atomic oxygen is needed (e.g., in low orbit around the Earth and in some industrial and scientific applications).

The top part of Figure 1 illustrates the preparation of the amine-terminated arylene ether (ATPAE) oligomers that contain phosphine oxide and that are used to prepare the copolymers. This reaction is aided by the phosphine oxide group, which is electron withdrawing and thereby activates the monomer to nucleophilic substitution. When the molar ratio of 2,2-bis(4-hydroxyphenyl)hexafluoropropane (BPAF) to bis(4-fluorophenyl)phenyl phosphine oxide (FPPO) in an experiment was 0.7825, the average molecular weight of the oligomer was 2,500 g/mole, and the oligomer was called ATPAE 2500. When the molar ratio of BPAF to FPPO was 0.8582, the average molecular weight was 4,000 g/mole, and the oligomer was called ATPAE 4000.

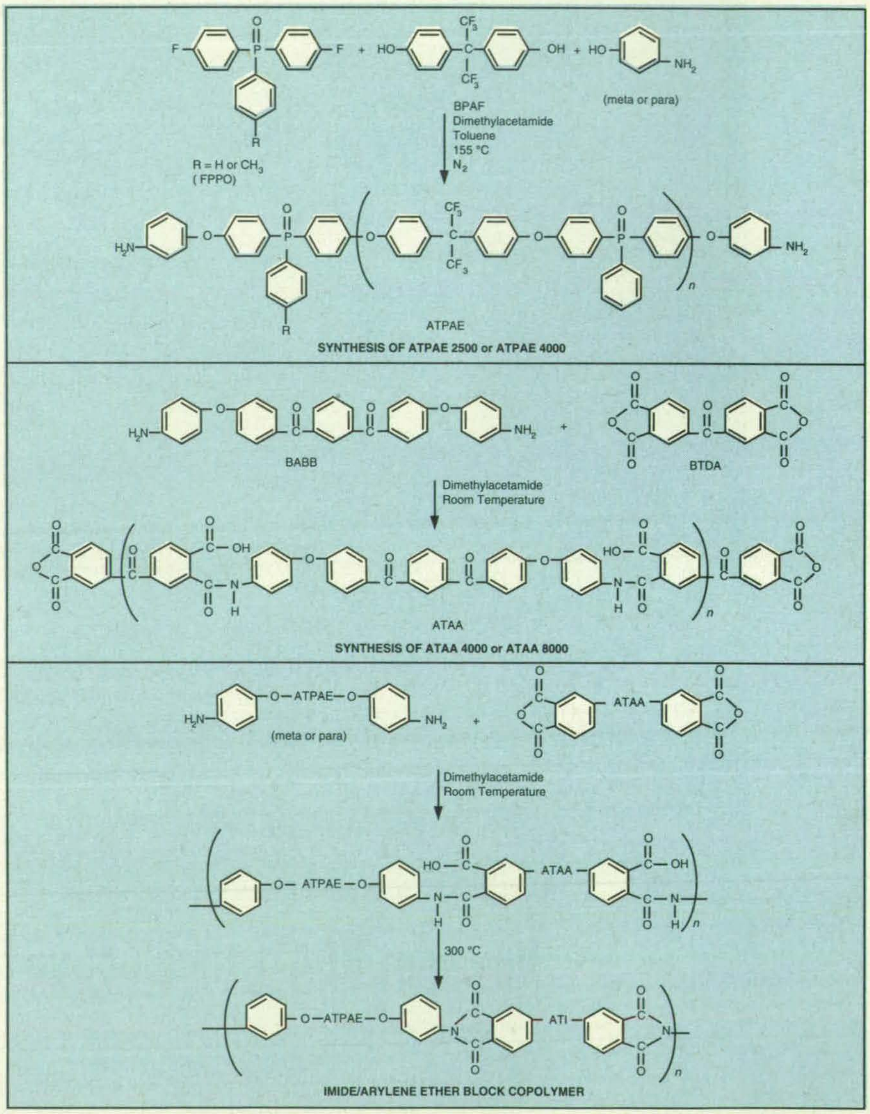


Figure 1. These **Reaction Schemes** are representative of those used to synthesize the precursors of phosphine oxide-containing imide/arylene ether copolymers and the copolymers themselves.

The middle part of Figure 1 illustrates the preparation of the anhydride-terminated amide acid (ATAA) oligomers used to prepare copolymers. When the molar ratio of 1,3-bis(4-aminophenoxy-4'-benzoyl)benzene (BABB) to 3,3',4,4'-benzophenonetetracarboxylic acid dianhydride (BTDA) in an experiment was 0.821, the average molecular weight of the oligomer was 4,000 g/mole, and the oligomer was referred to as ATAA 4000. When the molar ratio of BABB to BTDA was 0.906, the average molecular weight of the oligomer was 8,000 g/mole, and the oligomer was referred to as ATAA 8000. (After copolymerization and cyclodehydration, the blocks of the copolymers derived from these oligomers are denoted as ATI 4000 and ATI 8000, respectively.)

The bottom part of Figure 1 illustrates the copolymerization, at room temperature, of one of the anhydride-terminated amide acid oligomers described

above with one of the phosphine oxide-containing amine-terminated arylene ether oligomers described above, followed by cyclodehydration during curing (1 h each at 100 °C, 200 °C, and 300 °C) to produce the corresponding imide copolymer. The glass-transition temperatures of copolymers thus synthesized in initial experiments ranged from 224 °C to 228 °C. Solution-cast films of the block copolymers were tough and flexible: at a temperature of 23 °C, tensile strengths were as great as 16.1 kpsi (111 MPa), tensile moduli were as great as 439 kpsi (3.03 GPa), and elongations at break were as large as 23 percent, for example. These values are significantly greater than the corresponding values for the polyarylene ether homopolymer. Moreover, as shown in Figure 2, for example, the imide/arylene ether copolymer of ATPAE 4000 and ATI 4000 resisted etching by oxygen plasma better than did the commercial polyimide Kapton®.

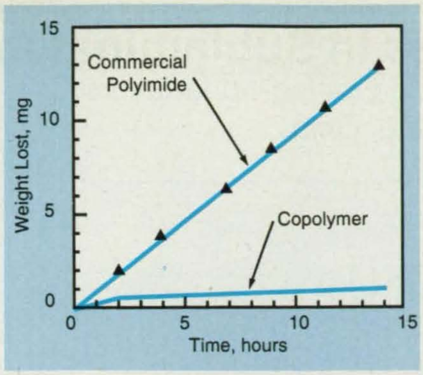


Figure 2. **Oxygen-Plasma Etching** of the imide/arylene ether copolymer of ATPAE 4000 and ATAA 4000 is compared with that of a commercial polyimide. The samples were 0.5 in. (1.27 mm) square.

This work was done by Brian J. Jensen of **Langley Research Center** *and Richard D. Partos of Analytical Services and Materials, Inc. For further information,* ***write in 80*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquires concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 24]. Refer to LAR-14925.

High-Emittance, Low-Absorbance Thermal-Control Coating

Aluminum is anodized in a modified process.

Lyndon B. Johnson Space Center, Houston, Texas

A modified process for anodizing 5657 aluminum alloy results in Al_2O_3 surfaces with infrared emissivities as great as 0.92 and solar absorptivities as small as 0.2. These values of emissivity and absorptivity are greater and lesser, respectively, than those of previous anodized coatings. Because of its greater emissivity, this coating could enable the fabrication of radiators requiring less surface, and hence less weight: radiators with this coating can weigh approximately 7 percent less than thermally equivalent radiators made with older anodizing processes. This anodized coating can be applied easily and economically, and it retains all of the desirable properties of standard anodized coatings — for example, resistance to wear, handling, and corrosion.

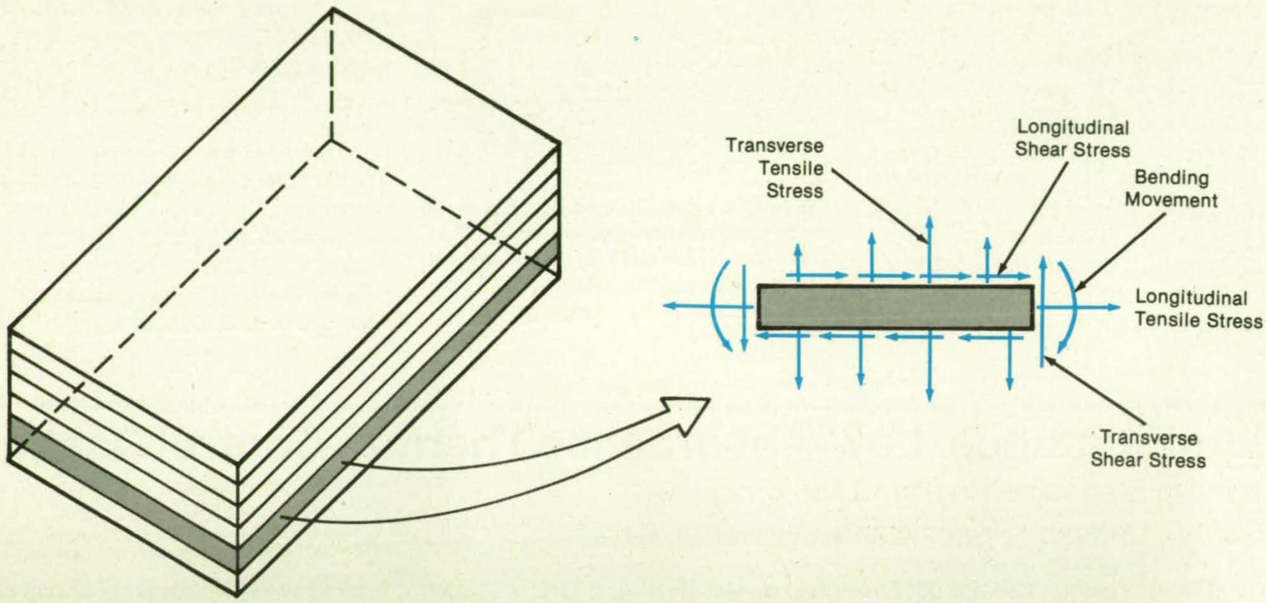
The principal novel features of the modified anodizing process are stepwise changes in current density and an acid-bath temperature greater than that of older anodizing processes. In preparation, the 5657 aluminum part to be anodized is alkaline cleaned by immersion in a solution of Turco 4090 (or equivalent) for 15 min at a temperature of 200 °F (93 °C) and rinsed with tapwater. Then it is chemically brightened by immersion for 45 s at the same temperature in a solution of 85 parts reagent-grade phosphoric acid and 15 parts reagent-grade nitric acid. The part is again rinsed with tapwater. After this bright-dipping treatment, the part is anodized in a 15 weight percent solution of reagent-grade sulfuric acid in a lead tank at a temperature of 30 °C. The anodizing current is supplied first at a density of 19 A/ft^2 (205 A/m^2) for 20 min, then 15 A/ft^2 (161 A/m^2) for 20 min, then 10 A/ft^2 (108 A/m^2) for 20 min. After this anodizing treatment, the part is sealed by immersion in a bath of demineralized water at 200 °F (93 °C) for 5 min. The part is then dried in air.

This work was done by Huong G. Le and Dudley L. O'Brien of McDonnell Douglas Corp. for **Johnson Space Center**. *For further information,* ***write in 102*** *on the TSP Request Card.*
MSC-21963

Analysis of Fractures in Sublaminates

Stresses and failures are predicted for individual layers.

Lewis Research Center, Cleveland, Ohio



A **Generic Ply in Equilibrium**, modeled by a plate-bending theory, is the basis for the equations of this method of analysis.

A computational procedure has been developed to predict the mechanical behavior and interactions of individual plies or sublaminates of fiber/matrix laminate structures. Embodied in a computer code, the procedure is useful for the computation of stresses in regions affected by delaminations, transverse cracks, discontinuities caused by manufacturing errors, configurations, and loading conditions.

The mathematical model of a layer is taken from a previous refinement of plate-bending theory. The model provides explicit distributions of stresses and displacements through the thickness. The model also deals with the prescribed stresses and displacements on the transverse (interlaminar) surfaces and enables the specification of at least five boundary conditions — three force resultants or deflections and two moment resultants or rotations (see figure).

The analysis can be applied to all the layers in a laminate or to only the few layers that surround defects. In the latter case, the remaining layers can be grouped into sublaminates and treated as homogeneous layers. Interlaminar stresses are initially assumed to be unknown. The enforcement of the continuity of displacement and traction at interfaces between layers leads to the final system of differential equations.

The local solutions of these equations are retained at only one edge of each of the layers; which edge depends on the particular problem. This is permissible as long as the resultant forces and moments defined for the layers at the edges where the solutions are dropped are statically equivalent to the local total loads applied to the whole edges. At the edges where the local solutions are retained, the boundary conditions can still be specified on each layer.

The strategy enables the stresses and displacements near discontinuities to be represented by functions with pure exponential decays, each of which is valid at only one edge of one layer. It eliminates the problem relating to precision that would normally be encountered in the use of exponential functions in the analysis of plies. As a result, the sublaminate/ply-level analysis can be extended to laminates with discontinuities in loads, in materials, and in configurations along the axes of the laminates, without any restriction on the number of layers.

The general method of analysis can handle different types of restraints routinely, without major changes in the final system of equations. The mathematical models illustrate how the stress field ahead of a crack tip responds to simple changes in the edge supports. This knowledge is important in designing fracture specimens for different modes of propagation of cracks. The computer code that was developed for this analysis is flexible with regard to the types of materials and loads, the number of layers, and the boundary conditions. Cracks may be in the plane of the laminate or through the thickness.

In conjunction with the concept of the strain-energy-release rate and the micromechanics of composites, the computational procedure was used to predict the behaviors of end-notch and mixed-mode fracture specimens. The computed stresses were in good agreement with those from a three-dimensional finite-element analysis; the predicted strain-energy-release rates compared well with the limited available experimental data.

This work was done by R. R. Valisetty and C. C. Chamis of **Lewis Research Center**. *Further information may be found in NASA TM-89827 [N87-20389], "Strain Energy Release Rates of Composite Interlaminar End-Notch and Mixed Mode Fracture: A Sublaminate/Ply Level Analysis and a Computer Code."*

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Mathematics and Information Sciences

Programs Help Create and Evaluate Markov Models

PAWS and STEM assist in analysis of behavior of a fault-tolerant computer system.

Traditional fault-tree techniques for analyzing the reliability of large, complicated systems fail to model mathematically the dynamic reconfiguration capabilities of modern computer systems. Markov models, on the other hand, can describe both recovery from faults (via reconfiguration of systems) and the occurrence of faults. The Pade Approximation With Scaling (PAWS) and Scaled Taylor Exponential Matrix (STEM) computer programs provide a flexible, user-friendly, language-based interface for the creation and evaluation of Markow models that describe the behaviors of fault-tolerant reconfigurable computer systems. PAWS and STEM produce exact solutions for the probabilities of system failures and provide conservative estimates of the numbers of significant digits in the solutions.

The calculation of the probability of entering a death state of a Markov model (representing system failure) requires the solution of a set of coupled differential equations. Because of the large disparity between the rates of arrival of faults and recoveries of systems, Markov models of fault-tolerant architectures inevitably lead to numerically stiff differential equations. Both PAWS and STEM have the capability to solve such equations numerically. These complementary programs use separate methods to determine the matrix exponential in the solution of a system of such equations. In general, PAWS is better suited to evaluate small and dense models. STEM operates at lower precision but works faster than PAWS does with larger models that contain fewer transitions among states.

The mathematical approach chosen to solve a reliabilty problem can vary with the size and nature of the problem. Although different solution techniques are utilized on different programs it is possible

to have a common input language. The Systems Validation Methods group at NASA Langley Research Center has created a set of programs that form the basis for a reliability-analysis workstation. The set of programs are the SURE reliability-analysis program (COSMIC program LAR-13789, LAR-14921); the ASSIST specification interface program (LAR-14193, LAR-14923); the PAWS/STEM reliability-analysis programs (LAR-14165, LAR-14920); and the FTC fault-tree tool (LAR-14586, LAR-14922). FTC is used to calculate the probability of the top event in a fault tree. PAWS/STEM and SURE are programs that interpret the same SURE language but utilize different methods of solution. ASSIST is a preprocessor that generates SURE language from a more abstract definition.

SURE, ASSIST, and PAWS/STEM are also offered as a bundle. Please see the abstract for COS-10039/COS-10041, SARA — SURE/ASSIST Reliability Analysis Workstation, for pricing details.

PAWS/STEM was originally developed for DEC VAX-series computers running VMS and was later ported for use on Sun computers running SunOS. The package is written in PASCAL, ANSI-compliant C language, and FORTRAN 77. The standard distribution medium for the VMS version of PAWS/STEM (LAR-14165) is a 9-track, 1,600-bit/in. (630-bit/cm) magnetic tape in VMSINSTAL format. It is also available on a TK50 tape cartridge in VMSINSTAL format. Executable codes are included. The standard distribution medium for the Sun version of PAWS/STEM (LAR-14920) is a 0.25-in.(6.35-mm) streaming-magnetic-tape cartridge in UNIX tar format. Both Sun3 and Sun4 executable codes are included. PAWS/STEM was developed in 1989 and last updated in 1991.

DEC, VAX, VMS, and TK50 are trademarks of Digital Equipment Corp. SunOS, Sun3, and Sun4 are trademarks of Sun Microsystems, Inc. UNIX is a registered trademark of AT&T Bell Laboratories.

This program was written by Ricky W. Butler of **Langley Research Center** *and David P. Boerschlein of Lockheed Engineering & Sciences Co. For further information,* ***write in 100*** *on the TSP Request Card. LAR-14920*

Program Aids in Printing FORTRAN-Coded Output

FORPRINT inserts the necessary printer-control codes.

The FORPRINT computer program prints FORTRAN-coded output files on most non-Postscript printers with such extra features as control of fonts for Epson and Hewlett Packard printers. Many FORTRAN programs put out data to printers or to data files with the first column of each set of data reserved for printer-control codes. Some printers do not respond to these codes during printing. FORPRINT rewrites the data to the printer and inserts the correct printer-control codes.

Alternative uses include the ability to separate a data or ASCII file during printing by use of editing software to insert a "1" in the first column of the data line that should start a new page.

FORPRINT is written in FORTRAN 77 for IBM PC-series compatible computers running MS-DOS, and Sun-series computers running SunOS. It has been successfully compiled and implemented using Lahey FORTRAN 77 under MS-DOS. When used on computers designed for MS-DOS, this program requires 50K of random-access memory (RAM) and MS-DOS v3.3 or later. It requires 184K of RAM under SunOS. The standard distribution medium for FORPRINT is a 5.25-in. (13.34-cm), 360K diskette in MS-DOS format. Documentation is included in the price of the program. FORPRINT was developed in 1990.

IBM PC is a registered trademark of International Business Machines Corp. MS-DOS is a registered trademark of Microsoft Corp. Sun and SunOS are trademarks of Sun Microsystems, Inc.

This program was written by Richard A. Akian of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 29*** *on the TSP Request Card. MFS-29901*

Neural-Network Object-Recognition Program

The HONTIOR neural network recognizes an object despite translation, rotation, or change of scale.

Neural networks have been applied in numerous fields, including transformation-invariant recognition of objects, wherein objects are recognized despite changes in the positions, sizes, or orientations of the objects. One of the more successful neural-network methods used in such invariant recognition of objects is the higher-order neural network (HONN) method. With an HONN, known relationships are exploited, and the desired invariances are built directly into the architecture of the network, eliminating the need for the network to learn invariance under transformations. This results in a significant reduction in the training time required, inasmuch as the network can be trained on only one view of each object, and it is not necessary to train it on numerous transformed views. Moreover, 100 percent accuracy is guaranteed for images characterized by built-in distortions, provided that noise is not introduced through pixelation.

The HONTIOR computer program implements a third-order neural network that exhibits invariance under translation, change of scale, and in-plane rotation. This invariance is incorporated directly into the architecture of the network. Thus, only one view of each object is needed to train the network for two-dimensional-translation-invariant recognition of the object. HONTIOR can also be used for three-dimensional-transformation-invariant recognition by training the network on only a set of out-of-plane rotated views.

Historically, the major deficiency of HONN's has been that the sizes of the input fields were limited to the sizes of the memories required for the large number of interconnections in fully connected networks. HONTIOR overcomes this deficiency by coarse-coding the input images (coding an image as a set of overlapping but offset coarser images). By use of this scheme, a large input field (4,096×4,096 pixels) can easily be represented in very little virtual memory (30 Mb).

The HONTIOR as distributed is divided into three main programs. The first program contains the training and testing routines for a third-order neural network. The second program contains the same training and testing procedures as does the first, but it also contains a number of functions to display and edit training and test images. The third program is an auxiliary program that calculates the included angles for an input field of a given size.

HONTIOR is written in the C language, and was originally developed for computers of the Sun3 and Sun4 series. Both graphic and command line versions of the program are provided. The command line version has been successfully compiled and executed both on computers that run on the UNIX operating system and on DEC VAX-series computers that run on VMS. The graphic version requires the SunTools windowing software environment, and therefore runs only on Sun-series computers. The executable code for the graphics version of HONTIOR requires 1 Mb of random-access memory. The standard distribution medium for HONTIOR is a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge in UNIX tar format. It is also available on a 3.5-in. (8.89-cm) diskette in UNIX tar format. The package includes sample input and output data. HONTIOR was developed in 1991.

Sun, Sun3, and Sun4 are trade-

marks of Sun Microsystems, Inc. UNIX is a registered trademark of AT&T Bell Laboratories. DEC, VAX, and VMS are trademarks of Digital Equipment Corp.

This program was written by L. Spirkovska and M.B. Reid of **Ames Research Center**. *For further information,* ***write in 104*** *on the TSP Request Card. ARC-13187*

Efficient Minimum-Polynomial and Reduced-Rank Extrapolation

This computer program is economical and easy to use.

The MPERRE computer program accelerates the convergence of a sequence of vectors by use of minimum-polynomial extrapolation (MPE) and reduced-rank extrapolation (RRE). MPE and RRE are very effective in accelerating the convergences of such sequences of vectors as those that are obtained from the iterative solution of systems of linear and nonlinear equations. In particular, MPE and RRE, in conjunction with various iterative techniques, have been successfully employed in the finite-difference solution of large-scale elliptic boundary-value problems and problems in computational-fluid-dynamics.

One important feature of both MPE and RRE is that the only input required is the sequence of vectors, the convergence of which is to be accelerated. This feature makes MPE and RRE very easy to use.

The definitions of MPE and RRE involve the least-squares solution of a system of linear equations, the number of equations in this system being the dimension of the vectors in the given sequence. Because this dimension may be very large, as in the case of two- and three-dimensional computational-fluid-dynamics problems, the solution of the least-squares problem by use of existing software packages may be expensive with respect to both time and core-memory requirements, while the less-expensive approach of normal equations may lead to serious loss of accuracy in many cases.

On the other hand, the implementations of MPE and RRE used in the present program are very inexpensive with respect to both time and core-memory requirements, and are stable numerically. In addition, they enable one to compute exactly for linear systems (or estimate for nonlinear systems) the accuracy achieved in the acceleration process without actually computing the residuals at each stage. This makes the task of minimization of errors very quick and economical.

The MPERRE program was written in FORTRAN 77 with double-precision variables. A simple change in source-code parameters enables the use of single-precision variables. MPERRE was developed on an IBM 370-series computer under VM and has been implemented on a variety of other computers. It is expected to be executable on any computer that is equipped with an ANSI standard FORTRAN 77 compiler. On a DEC VAX 3600 computer under VMS, the program requires 120K of main memory. The program is available on a 5.25-in. (13.34-cm), 360K MS-DOS format diskette (standard medium) or a 9-track, 1,600-bit/in. (630-bit/cm)magnetic tape in ASCII Card Image format. MPERRE was developed in 1990.

IBM 370 and VM are trademarks of International Business Machines Corp. DEC VAX 3600 and VMS are trademarks of Digital Equipment Corp. MS-DOS is a registered trademark of Microsoft Corp.

This program was written by Avram Sidi of Technion-Israel Institute of Technology for **Lewis Research Center**. *For further information,* ***write in 3*** *on the TSP Request Card.*
LEW-15162

Program Tracks Cost of Travel

Travel Forecaster is a menu-driven, easy-to-use program.

Planning business travel within an organization is often a time-consuming task. Travel Forecaster is a menu-driven, easy-to-use computer program that plans, forecasts cost, and tracks actual vs. planned cost of business-related travel of a division or branch of an organization and compiles this information into a data base to aid the travel planner. The ability of this program to handle multiple trip entries makes it a valuable time-saving device.

Travel Forecaster takes full advantage of the properties of a relational data base so that information that remains constant, such as per diem rates and airlines fares (which are unique for each city), has to be entered only once. A typical entry would include selection of the traveler's name and destination city by use of a mouse on popup lists, plus typed entries for number of travel days and purpose of the trip. Multiple persons can be selected from the popup lists, and multiple trips are accommodated by entering the number of days by each appropriate month on the entry form. An estimated travel cost is not required of the user, inasmuch as it is calculated by a "Fourth Dimension" formula.

With this information, the program can produce output of trips by month with subtotal and total cost for either organization or subentity of an organization; or it can produce outputs of trips by month with subtotal and total

cost for international (only) travel. It also provides monthly and cumulative formats of planned vs. actual outputs in data or graph form. Users can do custom queries to search and sort information in the data base, and the program contains a user-friendly report generator that can create custom reports.

Travel Forecaster 1.1 is a data-base program for use with Fourth Dimension Run-time 2.1.1. It requires a Macintosh Plus running System 6.0.3 or later, 2 Mb of random-access memory, and a hard disk. The standard distribution medium for this package is one 3.5-in. (8.89-cm) 800K diskette in Macintosh format. Travel Forecaster was developed in 1991.

Macintosh is a registered trademark of Apple Computer, Inc. Fourth Dimension is a registered trademark of Acius, Inc.

This program was written by Lemuel E. Mauldin III of **Langley Research Center**. *For further information,* ***write in 96*** *on the TSP Request Card. LAR-14826*

Ada to X-Window Bindings

This program provides an "Ada view" of some mostly-C-language programming libraries.

The X-Window software system and its constituent program libraries were developed almost entirely in the C programming language, and, therefore, there are well-defined C-language interface libraries for all X-Windows functions. The X-Windows programming environment consists of three layers of program libraries: the low-level X library, the intermediate-layer Xt Toolkit Intrinsics library, and one of various high-level widget libraries, OSF Motif being the most common widget library. The Ada to X-Window Bindings computer program was developed to provide Ada programmers with complete interfaces to the Xt Intrinsics and OSF Motif toolkits.

The Xt and Motif programming libraries consist of nearly three hundred C-language functions and a large number of C-language structure definitions and constants. To provide an "Ada view" of Xt and Motif, an entire Ada programming layer that hides the interface to the C-level libraries was added. A separate Ada procedure and type definition was written for each C-language function and structure definition. The specification presented to the Ada programmer consists almost entirely of Ada types and structures. An effort was made to minimize the number of type conversions between Ada and C views for which the applications programmer would have to be responsible.

This package of software is written in the Ada and C languages for use with UNIX systems running MIT's X-Window System, Version 11 Revision 4, with the OSF/Motif widget set. Two separate versions of the package are included: one for Motif 1.0 and one for Motif 1.1. This package was developed under ULTRIX on a DECstation 3100 computer and is designed to be UNIX-independent. For some UNIX systems, the code may require minor modifications. The standard distribution medium for this package is a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge in UNIX tar format.

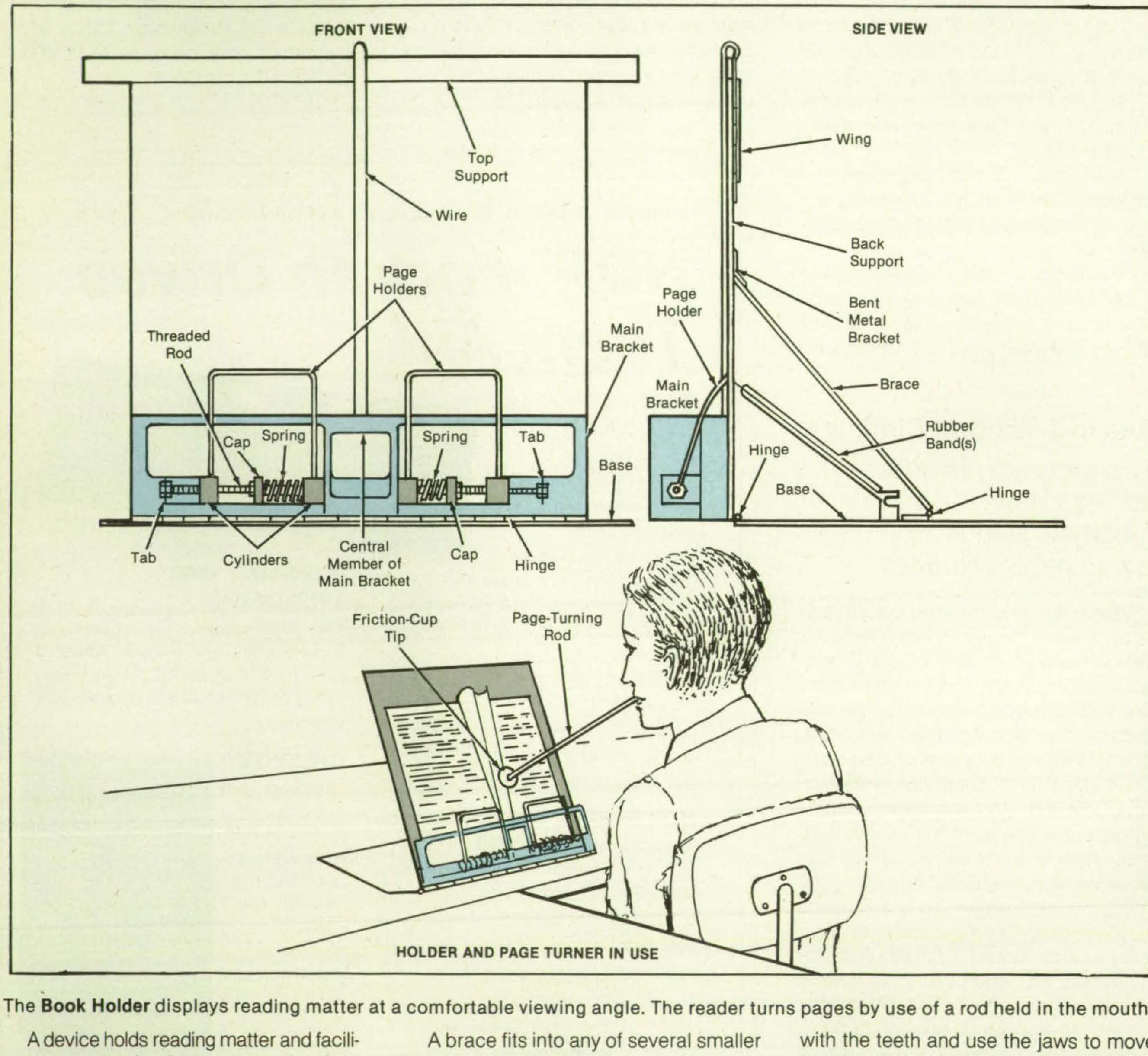
UNIX is a registered trademark of AT&T Bell Laboratories. X-Window System, Version 11 is a trademark of Massachusetts Institute of Technology. Motif is a trademark of The Open Software Foundation, Inc. ULTRIX and DECstation are trademarks of Digital Equipment Corp.

This program was written by Dean Souleles of Contract Software Service for **NASA's Jet Propulsion Labor-atory**. *For further information,* ***write in 106*** *on the TSP Request Card.*
NPO-18760

Book Holder and Page Turner for the Elderly and Handicapped

A quadriplegic can turn pages with little or no assistance.

Goddard Space Flight Center, Greenbelt, Maryland



The **Book Holder** displays reading matter at a comfortable viewing angle. The reader turns pages by use of a rod held in the mouth.

A device holds reading matter and facilitates page turning for a person who does not have use of arms and hands. The device accommodates a variety of publication formats, whether book, magazine, or newspaper. The holder sits on a hospital-bed table and can be adjusted to a convenient viewing angle.

The holder includes a flat upright back support for the reading matter, a hinged base, and a main bracket with bent-wire page holders (see figure). A top support on the back can be extended for such large items as newspapers. Wings on the back support also can be extended for oversize materials.

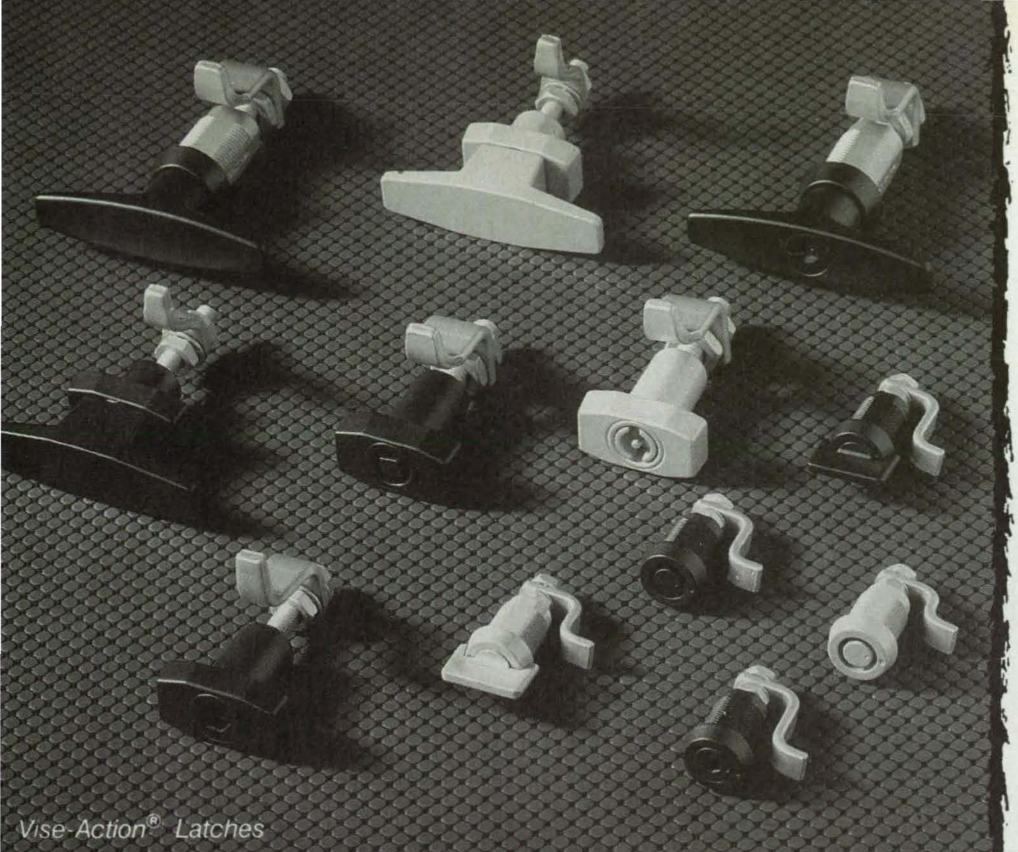
A brace fits into any of several smaller bent metal brackets on the rear of the back support to set it at the proper angle. Rubber bands hold the brace in the chosen bent metal bracket.

Springs press the page holders against the central member of the main bracket. The springs can be adjusted to vary the frictional torque on the page holders. A wire can be extended along the centerfold to hold the reading material in place.

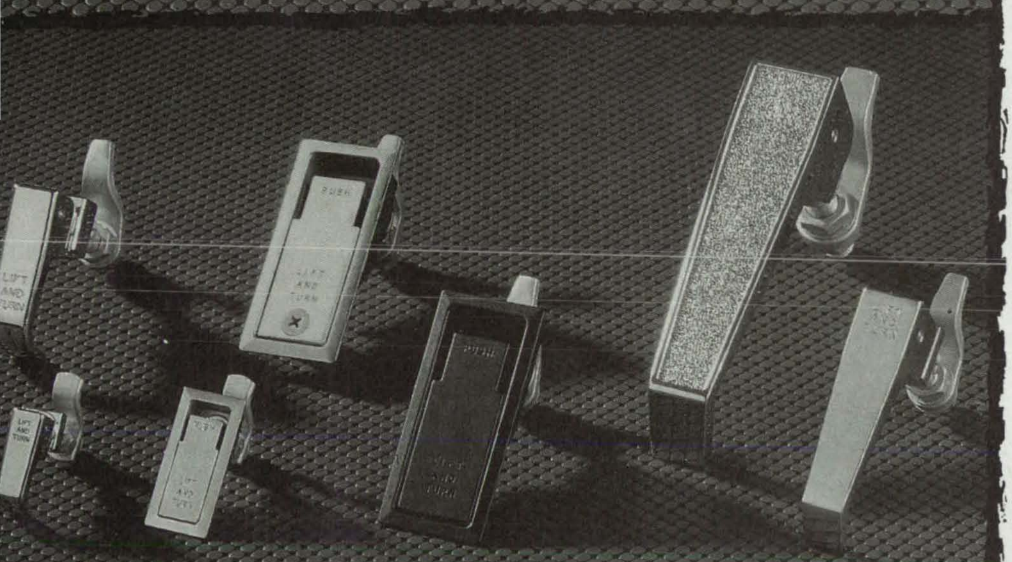
The reader turns a page by gripping a special rod via a mouthpiece, applying the friction cup at its tip to the page, and manipulating the rod. The mouthpiece is wide and tapered so that the user can grip it with the teeth and use the jaws to move it, rather than using the tongue or lips. This feature is particularly helpful to older people, whose facial and mouth muscles may be weak.

This work was done by James Kerley and Wayne Eklund of **Goddard Space Flight Center**. *For further information,* ***write in 5*** *on the TSP Request Card.*

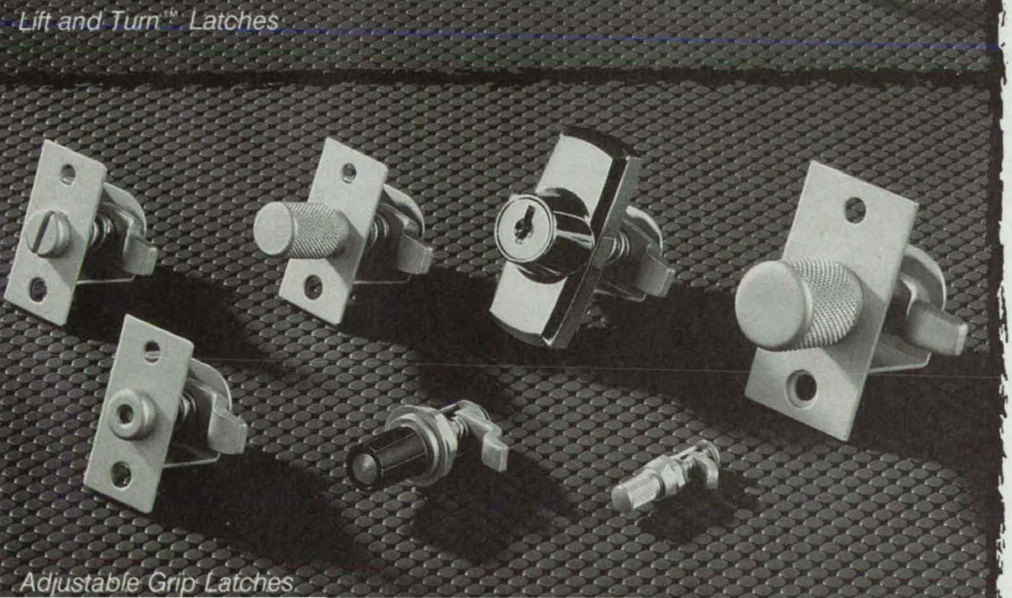
This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center [see page 24]. Refer to GSC-13415



Vise-Action® Latches



Lift and Turn™ Latches



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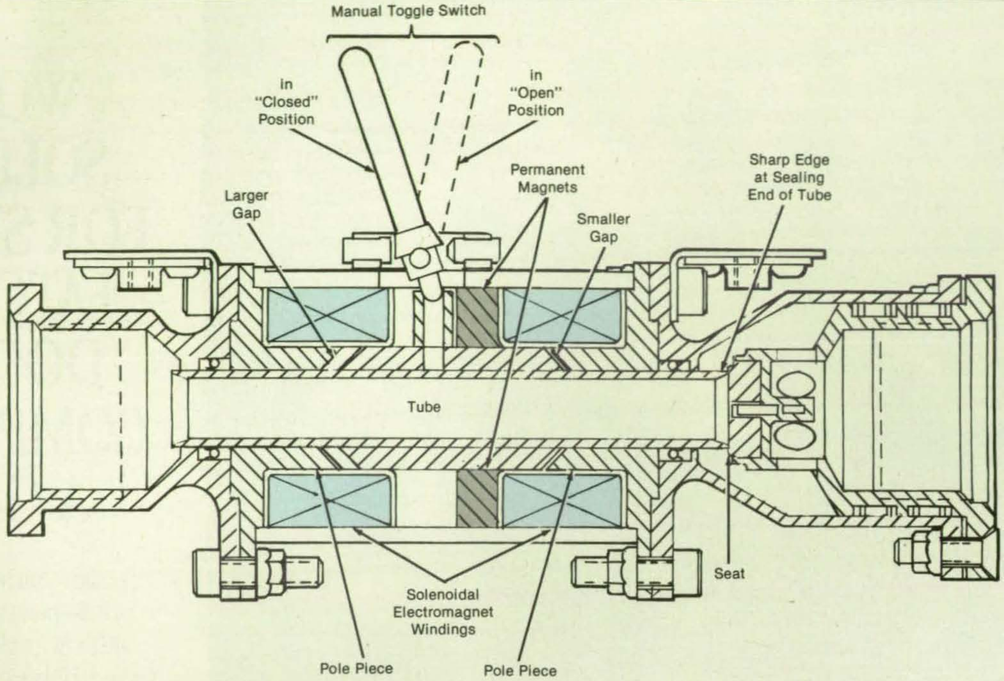
Dual-Latching, Solenoid-Actuated Tube Valve

A permanent magnet holds the valve on or off.

Marshall Space Flight Center, Alabama



The **Toggle Lever and Solenoidal Electromagnet Coils** enable manual or electrical switching of the valve between the open and the closed state.

A tube-type shutoff valve is electrically positioned to its open or closed state by a concentric solenoid. The solenoid is dual latching: it holds its position until it is changed electrically or manually.

In a tube valve, a central tube slides axially, closing off flow when it is held against a seat and allowing flow when it is backed away from the seat (see figure). With this arrangement, it is simple to balance the pressure on the seal between the seat and the sharp edge of the tube. With a pressure-balanced seal, only a small force is needed to hold the valve in position, regardless of the pressure acting on the valve. For example, the force needed to move the tube at an inlet pressure up to 1,000 lb/in.2 (about 7 MPa) is less than 5 lb (22.5 N) at a stroke of 0.093 in. (2.4 mm). A pressure-balanced tube valve is therefore well suited to actuation by a solenoid.

The precise shape required for pressure balance is ensured by first centerless-grinding the tube, then cutting one end (to be the sealing end) perpendicular to its outer wall, then sharpening this end so that the diameter of its seating edge is very close to the sealing diameter of the seat.

The armature of the solenoid is attached to the tube and contains permanent magnets that latch the armature and tube in the open or closed valve position with a force of 14 lb (62 N). The magnets increase the force as the tube penetrates the seat and the armature approaches the pole piece more closely. Shims are used to adjust the position of the seat relative to the end of the tube to obtain the desired penetration of the tube into the seat. Thus, a variety of seat materials can be accommodated, ranging from soft to hard.

The tube valve includes a manual toggle switch that can be used to override the permanent-magnet latch when an operator pushes the end of the toggle lever with a force of about 3 lb (about 13 N). Because the toggle moves in unison with the tube in any event, it provides a visual indication of the position of the valve. In addition, the valve contains two Hall-effect sensors that indicate its open or closed state on a remote display panel; these sensors respond to a small permanent magnet on the armature.

The latching magnets are mounted between two solenoid windings that encircle the tube. When no electrical power is supplied to either winding, the flux from the permanent magnets keeps the armature attracted to the pole piece from which it is separated longitudinally by the smaller gap, thereby latching the tube open or closed. Only a small force is needed to change the position, however. This is because, when current is applied to the winding near the larger gap, it sets up a flux that bucks the permanent-magnet flux in the smaller gap and a flux in the larger gap that creates an attractive force across this gap, thereby moving the armature to close the larger gap. As this gap becomes smaller, an increasing part of the permanent-magnet flux passes through it, providing an assist to the electromagnetic force and establishing a new latched position. Because it is necessary to energize the solenoid coil for only about 20 ms to establish the new latched position, little electrical energy is consumed in the process.

This work was done by Myron J. Brudnicki of Allied-Signal Aerospace Co. for **Marshall Space Flight Center**. *For further information,* ***write in 7*** *on the TSP Request Card.*

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457(f)], to the Allied Signal Aerospace Co. Inquiries concerning licenses for its commercial development should be addressed to

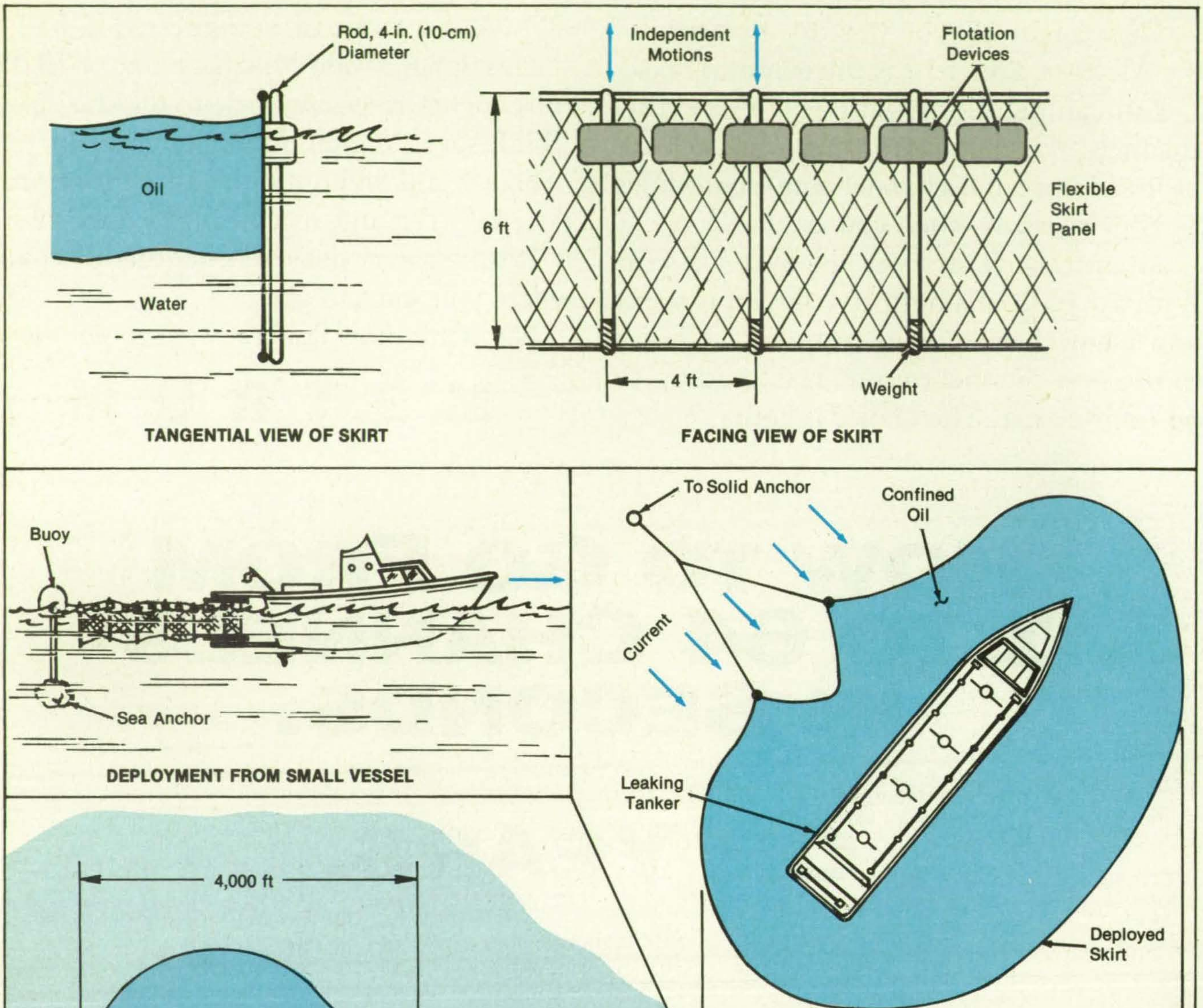
Allied Signal Aerospace Co.
Attn: Terry L. Miller, Patent Counsel
2525 West 190th St.
Torrance, CA 90504-6099

Refer to MFS-28714, volume and number of this NASA Tech Briefs *issue, and the page number.*

Deep Skirt Would Confine Oil Spilled in Water

The skirt would constitute a floating fence that would facilitate recovery.

Langley Research Center, Hampton, Virginia



The **Skirt Would Include Panels** joined to rods, which would hold the panels vertical. The skirt could be deployed from a small ship. The ship would pay out the skirt while moving in a circle from an anchored end; it would then join the ends, forming a loop around an oilspill.

A concept for confining marine oil spills and a variation for cleaning up oil slicks would simplify recovery of oil and reduce damage to adjacent water and land ecosystems. Both concepts involves a buoyant deep skirt that would be deployed by a ship to encircle a spill. Because the skirt would be deep, it would prevent confined oil from leaking over or under it.

The skirt would include flexible oil-impervious panels joined to vertical rods. A flotation device near the top of each rod would provide buoyancy, and a weight attached at the bottom of each rod would provide stability. Additional flotation devices could be placed on the panels. The skirt would ride with the waves and resist overturning. Anchors could be attached to prevent the skirt from drifting.

The version used to confine oil spills would be deployed around a leaking ship or oil platform. The depth of oil confined could become large, so the skirt needs to be adequately deep. As oil fills the skirt enclosure, the increasing pressure would force the panels outward until the largest possible area is enclosed. A relatively small perimeter could confine a large quantity of oil. For example, a skirt about 3,100 ft (about 960 m) long and 6 ft (1.8 m) high could confine about 25 million gallons (95 million liters). A skirt of this capacity could be carried on a relatively small vessel. Such a vessel might be carried on an oil tanker or mounted on an oil platform and launched quickly if a leak occurs. Alternately, small ships carrying skirts could be stationed near oil-transfer terminals.

When the oil has already spread to a larger area, a different tactic is used. Since the oil slick is very thin for this case, a much shallower skirt is used (i.e., 1 ft or 0.3 m high), but with a similar basic skirt design. A greater length would be deployed to enclose a large area. In the sketch, an area 4,000 ft (1,219 m) in diameter is enclosed. Since the boat and skirt are floating with the water currents, the forces on the skirt are small. The area enclosed by the skirt is then slowly decreased until the oil is thick enough for easy receiving. A deployable storage tank (bladder) can be used to hold the oil.

A combination of the two techniques would simplify recovery of most of the oil from a spill. The deep, relatively-small-diameter containment volume around the leak would minimize evaporation of oil and mixing with sea water. The slick-confining skirt could then capture most of the rest of the spill, thereby making recovery more nearly complete.

This work was done by Leonard M. Weinstein of **Langley Research Center**. *No further documentation is available.*

This is the invention of a NASA employee, and patent application may be filed. Inquiries concerning license for its commercial development may be addressed to the inventor:

Mr. Leonard M. Weinstein
13 Burke Avenue
Newport News, VA 23601

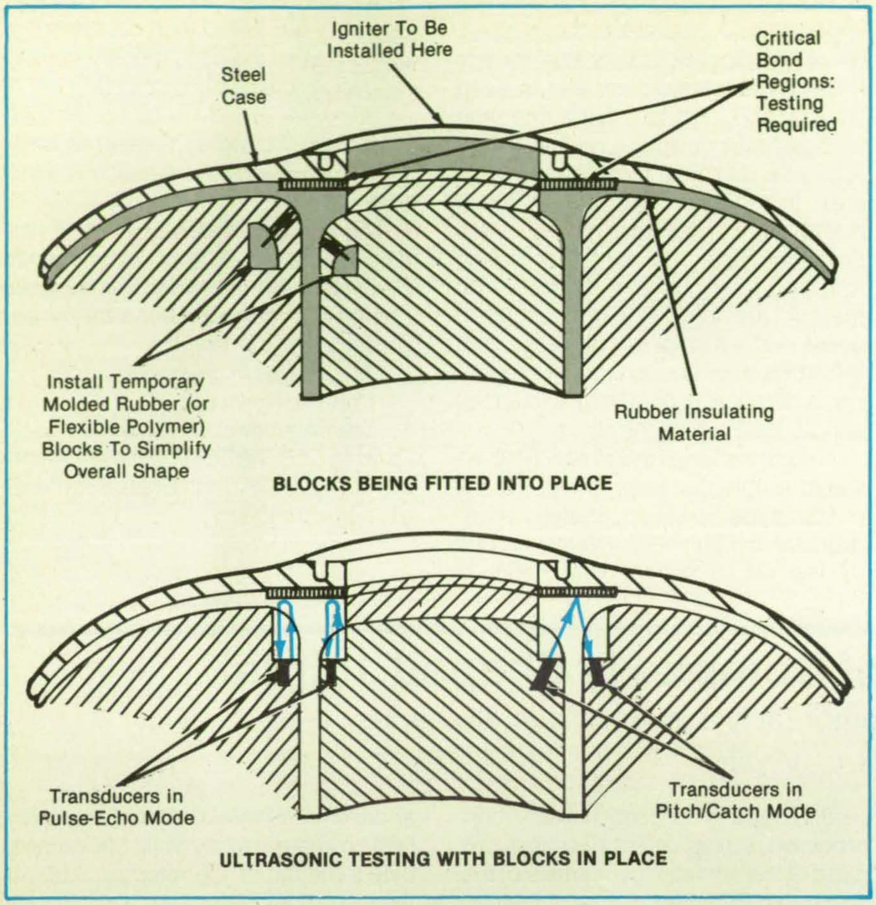
Refer to LAR-14695, volume and number of this NASA Tech Briefs *issue, and the page number.*

Ultrasonic Probing of Complexly Shaped Joints

Pieces of material are installed temporarily to simplify overall shapes.

Langley Research Center, Hampton, Virginia

A novel technique developed at NASA Langley Research Center involves the use of ultrasonics to inspect the first bond surfaces (case to insulation) of solid-rocket-motor joints. In these areas, tangential x-ray and conventional ultrasonic inspection techniques are inaccurate because of the complex geometries of the structures. By fitting pieces of insulating materials (or polymer materials with approximately similar acoustic properties) to mate exactly with the complicated shapes of the affected parts of the insulation, the complicated shapes are redefined into simpler ones that can



Molded Blocks Fitted to Complicated Shapes simplify overall shapes, thereby enabling ultrasonic probing of bonds between the steel case and the insulating material. These views are cross sections of the forward-dome-to-igniter seal at the top of a solid rocket motor.

be probed more easily.

When one uses this technique to insonify from the insulation side, one can readily detect the difference between a disbond and a good bond. Because the acoustic impedance of the insulation is typically lower than that of the case material, the phase of the acoustic signal from a disbond is typically inverted in comparison with the phase of a signal from a good bond.

The example shown in the figure represents the region of a solid rocket motor known as the forward-dome-to-igniter flange. Because of the curvatures and changes in thickness of the metal and the insulation, this region is currently uninspected. The placement of two blocks of shaped insulation material to square up the region results in a simpler geometry. In this simpler geometry, pulse-echo transducers can be used to scan and measure the regions away from the protruding inhibitor insulation.

In the regions under the protruding inhibitor insulation, pitch/catch ransducers can be used. The same technique can be applied to field tang joints, field clevis joints, and aft-dome-to-fixed-nozzle-housing attachment points. Although this technique was developed specifically for inspecting joints in solid rocket motors, it is also applicable to nondestructive evaluation of other complicated joints.

This work was done by Eric I. Madaras of **Langley Research Center**. *No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquires concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 24]. Refer to LAR-14626.

Transpiration Control of Aerodynamics Via Porous Surfaces

Effects of porosity would be modified to enhance the performances of aircraft.

Langley Research Center, Hampton, Virginia

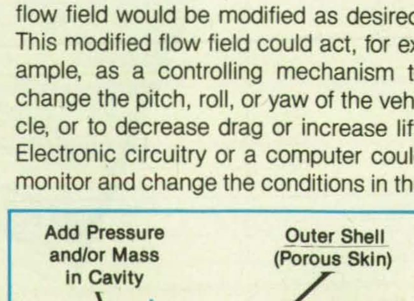
A quasi-active porous surface would be used to control the pressure loading on the aerodynamic surface of an aircraft or other vehicle, according to a proposal. Passive porosity alone modifies the aerodynamic characteristics of such a surface. With the addition of transpiration control, the effect of the passive porosity can be augmented or inhibited.

In transpiration control, one makes small additions of pressure and/or mass to a cavity beneath the surface of a porous skin on the aerodynamic surface, thereby affecting the rate of transpiration through the porous surface. In a previous method, the effect of porosity was controlled mechanically; e.g., by sliding a second "skin" beneath the surface either to cover or uncover parts of holes. The proposed transpiration-control method is low in mechanical complexity and offers advantages over the previous method.

The degree of porosity of the porous skin in the proposed method would be 10 to 20 percent, and individual holes would have diameters of approximately 0.025 in. (0.64 mm). The porous skin would be located on a forebody or any other suitable aerodynamic surface, with a cavity just below the surface.

The depth of the cavity could be as little as approximately two boundary-layer thicknesses. The pressure and/or the flow of mass into or out of this cavity would be altered by means of bleed air, vacuum pump, or stored pressure. The cavity beneath the surface could be compartmented into many smaller cavities so that the region above each cavity could be controlled separately, or, if desired, the regions could be interconnected.

The flow field would be controlled by locally augmenting or inhibiting the effect of the passive porosity so that the overall flow field would be modified as desired. This modified flow field could act, for example, as a controlling mechanism to change the pitch, roll, or yaw of the vehicle, or to decrease drag or increase lift. Electronic circuitry or a computer could monitor and change the conditions in the



Transpiration Control, shown here on a forebody, would augment or inhibit the effect of passive porosity so that the overall flow field would be modified as desired.

cavities to obtain the desired flow.

The transpiration control is passive in the sense that the flow field is allowed to modify itself. However, it is quasi-active in the sense that the conditions in the cavities are changed actively. A device based on this concept would be extremely lightweight, would be mechanically simple, would occupy little volume in the vehicle, and would be extremely adaptable.

This work was done by Daniel W. Banks, Richard M. Wood, and Steven X. S. Bauer of **Langley Research Center**. *No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 24]. Refer to LAR-14682.

Pivoting-Head Wrench

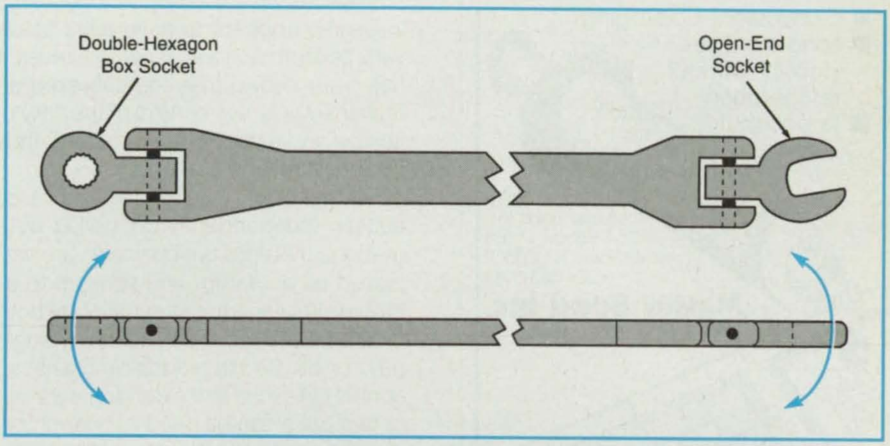
Pivoting heads function in tight spaces.

John F. Kennedy Space Center, Florida

A wrench has ends that pivot so that it can be used to loosen or tighten nuts or bolts in confined spaces. One end is equipped with an open-end socket; the other end, with a double-hexagon socket (see figure).

The heads pivot on pins. The pins fit tightly so that the heads do not flop; the friction on the pins is sufficient to hold the heads in their positions until they are rotated intentionally.

This work was done by Glen L. Bradley of **Kennedy Space Center**. *For further information,* ***write in 59*** *on the TSP Request Card.* KSC-11596



Versions of the **Pivoting-Head Wrench** can be made in a variety of sizes and torque capacities.

Active Suppression of Vibrations on Elastic Beams

Piezoceramic elements are used to control the transmission of flexural and extensional waves simultaneously.

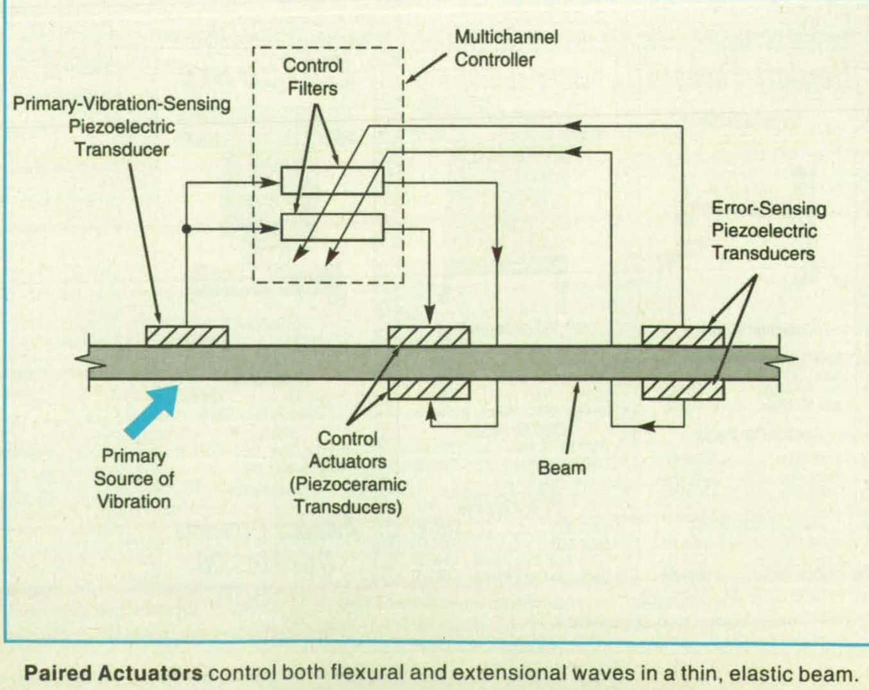
Langley Research Center, Hampton, Virginia

In many aerospace and marine structures, vibration generated by attached machinery is a serious problem. Often, vibrations travel through such a structure as flexural, extensional, and torsional waves and also may ultimately radiate as sound. All previous work on control of vibrations in beams appears to have dealt solely with flexural motions. Now, however, it has been shown that one can exert simultaneous active control of the flow of flexural and extensional waves and thus power on beams of arbitrary length.

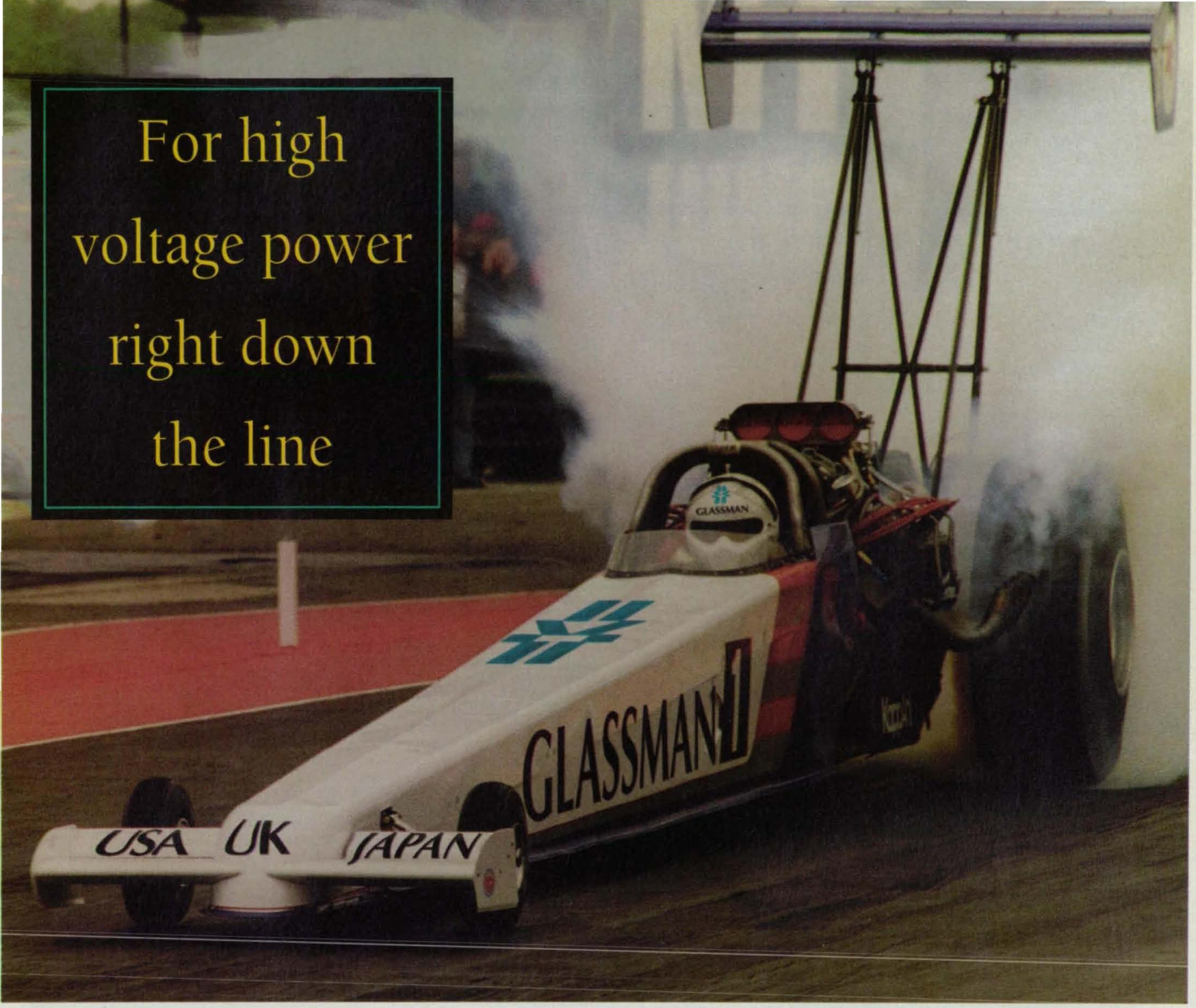
Pairs of colocated piezoelectric transducers, independently controlled by a multichannel adaptive controller, are employed as actuators and sensors to achieve simultaneous attenuation of both extensional and flexural motion. A single pair can be used to provide simultaneous control of flexural and extensional waves, or two pairs can be used to control torsional motion also. This capability is due to the nature of piezoelectric transducers, which, when bonded to the surfaces of structures and activated by oscillating voltages, generate corresponding oscillating distributions of stresses in the structures. The phases and amplitudes of the actuator voltages are adjusted by the controller to impede the flow of vibrational energy simultaneously, in waves of various forms, beyond the locations of the actuators.

In the figure, a thin elastic beam is shown transmitting a vibration from a primary source. Both flexural and extensional waves are assumed to exist and to be sensed by error-sensing piezoelectric transducers. The output of a sensing piezoelectric transducer on the beam near the primary source of vibration (or, alternatively, some other signal related to the primary source of vibration) is fed to control filters in the multichannel controller. The outputs of these control filters are then sent to two piezoelectric transducers that serve as control actuators. The parameters of the control filters are adjusted in such a way as to minimize the responses of the error-sensing piezoelectric transducers. Provided that the error-sensing transducers are predominantly sensitive only to the unidirectional wave components that travel away from the primary source of vibration, the flow of vibrational power to the right of the control-actuator transducers can be reduced.

This concept applies equally to harmonic or random response of a structure and to multiple responses of a structure to transverse bending, torsion, and compression within that structural element. This system has potential for many situations in which the predominant vibration transmission path is through a framelike structure. Such vibrations can



Paired Actuators control both flexural and extensional waves in a thin, elastic beam.



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For More Information Write In No. 558

reduce fatigue life or radiate sound at significant levels.

This work was done by Richard J. Silcox of **Langley Research Center** *and Chris R. Fuller and Gary P. Gibbs of Virginia Polytechnic Institute & State University. For further information,* ***write in 124*** *on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 5,156,370). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 24]. Refer to LAR-14508.

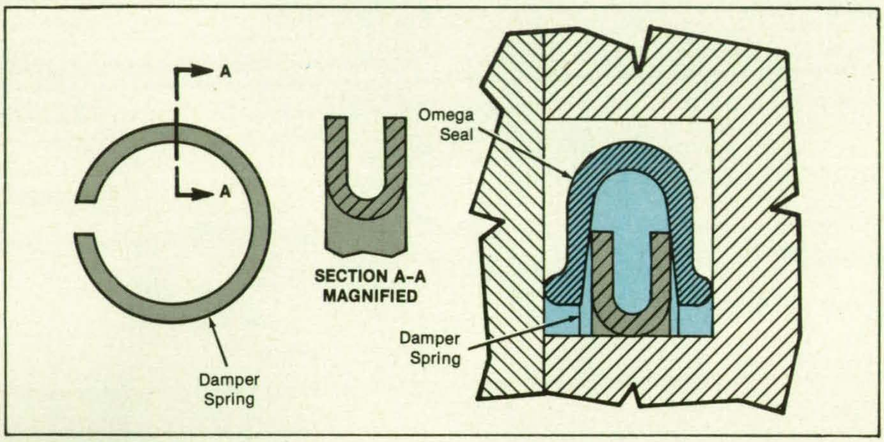
Damper Spring for Omega Seal

The spring reduces deflections of the seal.

Marshall Space Flight Center, Alabama

A damper spring reduces deflections of an omega-cross-section seal, thereby reducing the probability of failure and extending the life of the seal. The damper spring is a split ring with a U-shaped cross section (see figure). It is placed inside the omega seal and inserted with the seal into the seal cavity.

As the omega seal is compressed into the cavity, the spring and seal make contact near the convolution of the seal, and so the spring becomes compressed also. During operation, when the seal is dynamically loaded, the spring limits the deflection of the seal, thereby reducing the stress on the seal.



The **U-Shaped Spring** nests in the omega-cross-section elastomeric seal. The spring helps to extend the life of the seal.

This work was done by Scott T. Maclaughlin and Stuart K. Montgomery of United Technologies Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 24]. Refer to MFS-28689.

Matching Experimental and Analytical Aerodynamic Data

Three methods of correction-factor calculation have been developed and evaluated using airfoil test data.

Langley Research Center, Hampton, Virginia

Correction-factor methodologies have been developed to enable the use of experimental or analytical steady pressures or forces to correct calculations of steady and unsteady aerodynamic flows. Correction factors are multipliers that are applied to aerodynamic downwashes or pressures in aerodynamic calculations to achieve specified objectives.

Three methods of calculating correction factors have been developed to match steady lifting distributions of pressure, forces and moments on airfoil sections, and total forces and moments. Data for a rectangular supercritical wing that was tested in the NASA Langley Research Center Transonic Dynamics Tunnel have been used to determine correction factors to match distributions of surface pressure for mach numbers ranging from 0.266 to 0.8. These correction factors have also been applied to calculations of unsteady aerodynamic flow, and comparisons have been made with oscillatory experimental data for a range of reduced frequencies at several mach numbers.

The first of the three methods requires a match between analytical and experimental lifting distributions of pressure, the second requires characteristics of the airfoil section to be matched, and the third matches total forces or integrated pressures. The first and second methods require interpolation of experimental pressure data from the measurement stations to the analytical box locations.

For the first method, the correction factors are calculated as the ratios of the derivatives of experimental pressures to derivatives of analytical pressures at discrete points on the wing. The second method is similar, but the correction factors are ratios of properties of sections. Optionally, optimization techniques can be used to determine correction factors that minimize errors in the properties of sections and/or minimize the change in the analytical distribution of pressure. The third method uses optimization techniques to determine correction factors so that total forces, moments, or control derivatives are matched.

These methods of combining analytical and experimental data should lead to more-accurate predictions of the performance of airfoils. The methods can also be applied to such airfoils as those in gas-turbine engines, fans, and wind turbines.

This work was done by Carol D. Wieseman of **Langley Research Center**. *Further information may be found in NASA TM-100592 [N88-23728]. "Methodology for Matching Experimental and Analytical Aerodynamic Data."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LAR-14244

Thermal-Stress Reducer for Metal/Composite Joint

A link reduces stresses caused by different coefficients of thermal expansion.

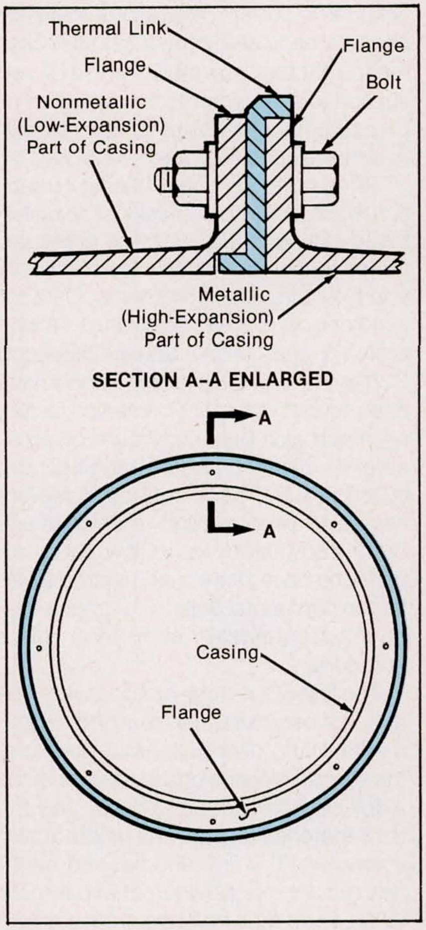
Lewis Research Center, Cleveland, Ohio

A simple insert called a "thermal link" reduces stresses caused by mismatches between the thermal expansions of a metal part and a nonmetallic part made of a fiber/matrix composite material. The link was conceived for use in the casing of an advanced jet engine, in which, for example, a part of the casing made of graphite/polyimide or ceramic-matrix composite is joined to another part of the casing made of aluminum or a metal-matrix composite.

The coefficients of thermal expansion of graphite/polyimide and ceramic-matrix composites range from 1.0×10^{-6} to 1.9×10^{-6} $(°F)^{-1}$ [1.8×10^{-6} to 3.4×10^{-6} $(°C)^{-1}$], while those of aluminum, titanium, and metal-matrix composites range from 4.0×10^{-6} to 12.5×10^{-6} $(°F)^{-1}$ [7.2×10^{-6} to 22.5×10^{-6} $(°C)^{-1}$]. Thus, a metal casing, as it is heated, could grow outward at a rate as high as 12.5 times that of the nonmetallic composite to which it is attached. Clearly, this difference would create a large shear stress at the joint.

The thermal link is designed to relieve much of this stress. Bolted between the low-expansion and high-expansion parts of the casing, it snap-fits to the inside of the low-expansion casing and the outside of the high-expansion casing (see figure). It is made of a material that has a coefficient of thermal expansion about midway between those of two casing sections; typically, 2.5×10^{-6} to 6.0×10^{-6} $(°F)^{-1}$ [4.5×10^{-6} to 10.8×10^{-6} $(°C)^{-1}$]. The thermal link thus serves as a buffer between the two parts of the casing, reducing the transverse shear stress in each part to about a 40 percent of its value without the thermal link. Regardless of the expansion, the thermal link retains its snap fit on the two parts. The bending and pressure stresses imposed on the flanges and the adjacent casing sections are almost unchanged. These stresses are transferred through the bolts and flanges, as they would be without the thermal links.

A thermal link to join graphite/polyimide to titanium can be made, for example, of an arc-cast molybdenum alloy that contains a small amount of titanium (less than 0.5 percent) for strength and a small amount of tungsten chosen to obtain the desired coefficient of expansion. This material can be exposed to temperatures up to 3,800 °F (about 2,100 °C), although a protective coat is needed above 930 °F (about 500 °C) to prevent oxidation.



The **Thermal Link Encircles** the casing of an engine at the junction of metallic and nonmetallic parts. It absorbs a large part of thermal-expansion-mismatch stress between the parts.

This work was done by Robert L. Glinski of United Technologies Corp. for **Lewis Research Center**. *For further information,* ***write in 74*** *on the TSP Request Card. LEW-15232*

Droplet Evaporator for High-Capacity Heat Transfer

A proposed heat-exchange scheme would boost heat transfer per unit area.

Lyndon B. Johnson Space Center, Houston, Texas

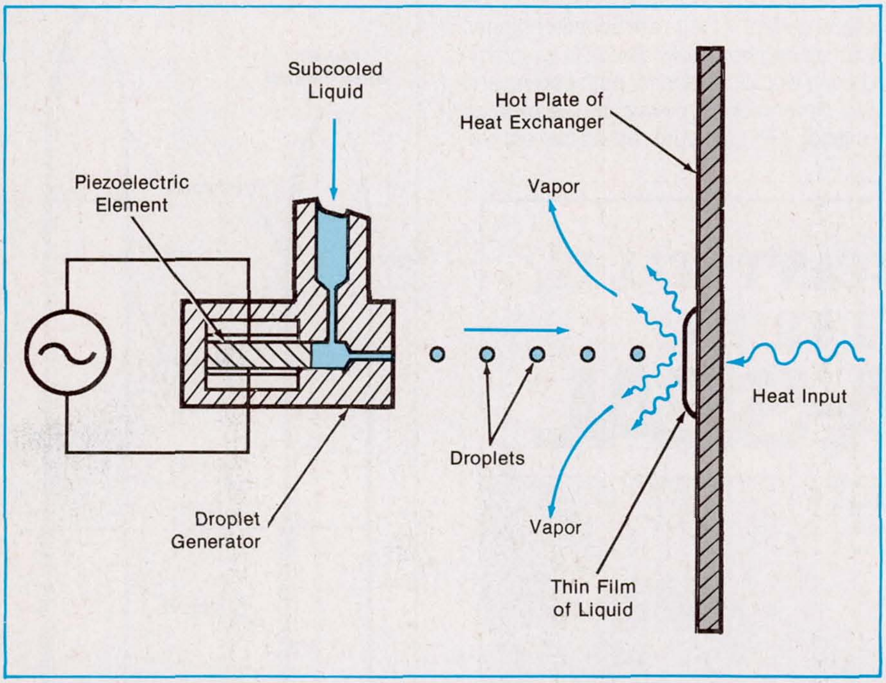


Figure 1. The **Generator Would Fire Droplets** of subcooled liquid at a hot plate. On impact, the droplets would spread out and evaporate almost instantly, removing heat from the plate. In practice, many generator nozzles would be arrayed over the evaporator plate.

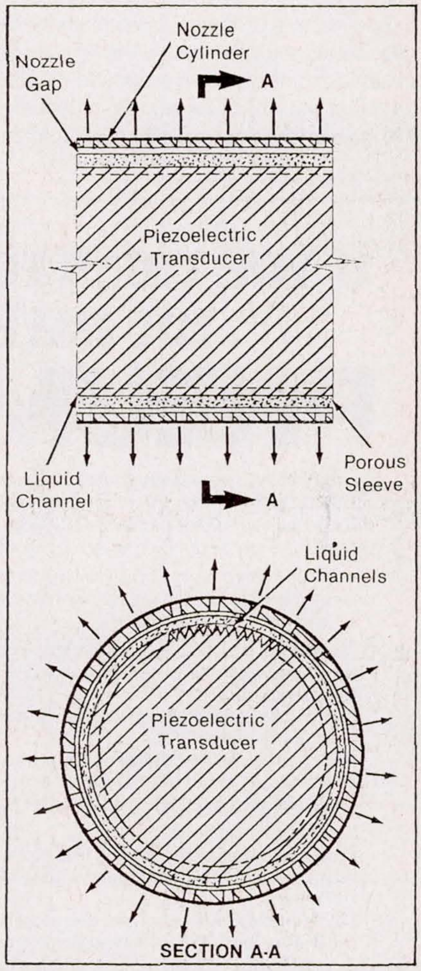


Figure 2. A **Cylindrical Droplet Generator** would spray liquid onto a hot outer cylinder.

A conceptual droplet evaporator would transfer heat at rates an order of magnitude greater than those of the best currently available heat exchangers. A stream of high-speed droplets would be directed at a surface heated above the saturation temperature of the droplet fluid (see Figure 1). On impact, the droplets would spread out in a film only a few micrometers thick. With its very large ratio of surface area to volume, the film would evaporate almost instantaneously, removing heat from the evaporator surface.

The droplets would be generated by piezoelectric nozzles like those in high-speed ink-jet printers. This type of nozzle can produce up to 100,000 droplets per second with diameters between 30 and 100 μm and speeds from 10 to 30 m/s. Multiple nozzles would be needed, and they would have to be spaced closely (piezoelectric nozzles only 0.1 mm apart have already been demonstrated). Temperature feedback would be used to adjust the rate of generation of droplets and to maintain the heat sink at a constant temperature.

The droplet evaporator would provide high rates of heat flux because the drag between the liquid and vapor is much smaller than in nucleate boiling or conventional spray cooling. The droplet evaporator would rely on the inertia of the droplets to counter the interphase drag. Because the speed of the droplets would be high and the fraction of the volume of the vapor occupied by the droplets would be low, the drag would be low.

The droplet evaporator could be used in a variety of heat exchangers. For example, it could be connected in a closed loop to a condenser coupled to a thermal bus. The evaporator would function as a heat-flux amplifier to handle a concentrated heat load, or it could be connected as an integral part of a two-phase bus and its vapor returned to the thermal bus. In another variation, the droplet evaporator would serve as the evaporator in a Rankine power cycle. The exterior wall of the evaporator might be the receiver in a dynamic solar-power cycle, for instance.

The key component in the droplet evaporator is the droplet generator. It must produce drops of uniform size and speed that follow well-controlled trajectories. In one conceptual design (see Figure 2), the generator would include a cylindrical tube with 100-μm nozzle holes drilled in a hexagonal pattern on a 500-μm pitch. Inside the tube, a piezoelectric transducer would expand and contract in the radial direction. A fluid-filled gap 20 to 50 μm wide would separate the transducer and the tube.

A voltage pulse would expand the transducer diameter by 6.5 μm. In expanding, the transducer would push a 100-μm droplet through each nozzle hole. The transducer would then contract to its original diameter. The expansion/contraction cycle would last 10 to 20 μs. In the 20 ms between pulses, the capillary forces in the nozzle holes would pump liquid into the gap, readying the nozzles for the next cycle.

This work was done by Javier A. Valenzuela of Creare Engineering Research and Development for **Johnson Space Center**. *For further information,* ***write in 28*** *on the TSP Request Card.* *MSC-21300*

Atlas Centaur Rocket With Reusable Booster Engines

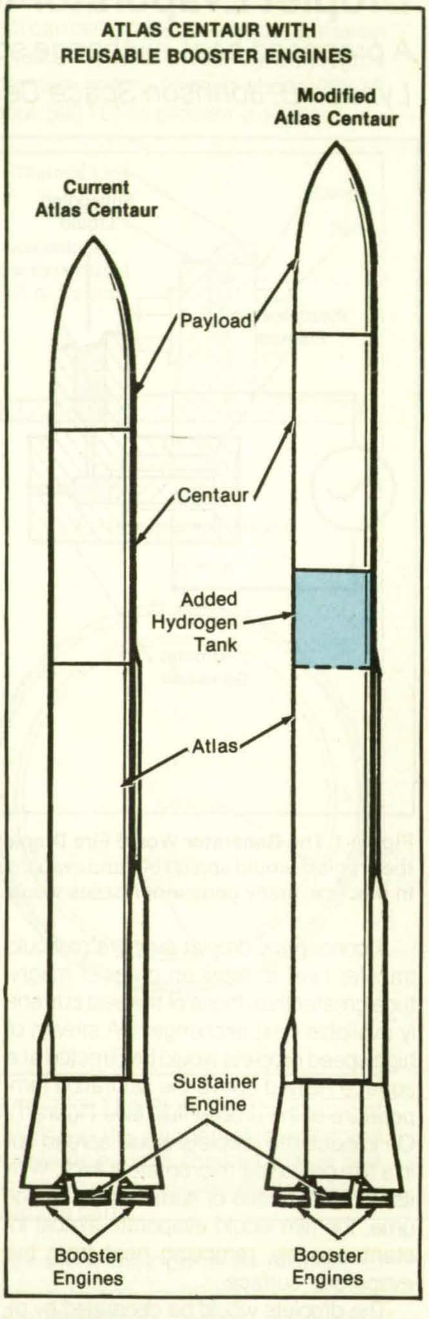
Recoverable, reusable booster engines would contribute significantly to reduction of cost.

Langley Research Center, Hampton, Virginia

The current Atlas Centaur is an expendable launching rocket that includes the hydrogen/oxygen Centaur upper stage. The Atlas stage includes booster engines that are dropped during ascent. After the booster engines are dropped, the sustainer engine continues to burn until the Atlas propellants are depleted. A proposed modification of the Atlas Centaur would enable the reuse of the booster engines. The Atlas Centaur is particularly appropriate for the proposed modification because the booster engines are dropped during ascent and because hydrogen is used in the Centaur.

The modification would include the replacement of the current booster engines with an engine of new design in which hydrogen would be used for both cooling and the generation of power. In the existing engines, RP-1 (a hydrocarbon fuel equivalent to a refined kerosene) is used as a coolant, and this could lead to coking and clogging in coolant passages or in turbines. The use of hydrogen in the new engine would eliminate coking and clogging and would improve performance significantly. To contain the needed hydrogen, a new tank must be added to the Atlas. Preliminary calculations indicate that a tank (see figure) about 12 feet (about 3.7 meters) long would be sufficient.

Three options are proposed for the booster engines. First, the engines could be



The **Added Tank** would provide hydrogen for cooling and the generation of power.

mounted in vehicles of lifting shape that could glide to a landing site. This option would avoid any problems related to the recovery of the engines from saltwater and the attendant problems of preparing the engines for reuse. The second option would involve the addition of a parachute system and flotation equipment to enable the recovery of the booster engines from the ocean. The third option would involve the sustainer engine.

In the first two options, the current sustainer engine would be used. For the third option, the new engine design would also be used for the sustainer engine. Rather than using a new sustainer engine for each flight, engines that had been used on the booster could be used as the sustainer engines. In an ideal situation, each new engine would be used twice as a booster engine, then used once as a sustainer engine and expended. In the third option, the new sustainer engines would have about the same thrust as that of the current booster engine, which is higher than the thrust of the current sustainer engine. Therefore, the booster engines could be staged at a lower velocity, reducing the difficulty of recovering them.

The primary advantage of the proposed modification would be reduction of cost. A secondary benefit would be increased reliability. Engines that have been used in flight before are less likely to contain undetected defects than are engines that have been tested only on the ground. Another benefit would be increased payload for the Atlas Centaur, primarily because the new engines with hydrogen cooling would provide a higher specific impulse than the current engines do.

This work was done by James A. Martin of **Langley Research Center**. *No further documentation is available.*
LAR-14167

Compact Robotic Vehicle

A radio-controlled microrover features light weight and agility.

NASA's Jet Propulsion Laboratory, Pasadena, California

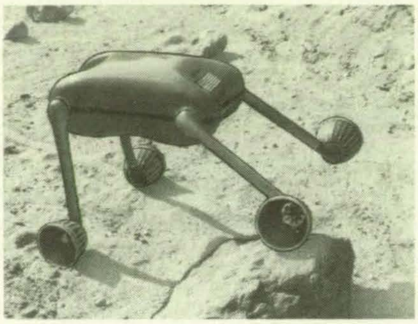
A miniature robotic vehicle, called Go-For, implements a new fork-wheeled mobility concept to traverse extremely rough terrain. The vehicle (see figure), which weighs 4 kg and is 0.4 m long, can climb over obstacles as large as 60 percent of its length. The mobility concept can be applied to much larger vehicles. At the same time, Go-For demonstrates the utility of microrovers for such applications as exploration of planetary surfaces, military surveillance, and assessing hazardous situations.

Go-For is a four-wheel skid-steered vehicle in which the front and rear pairs of wheels are extended on forks that can be rotated with respect to the body of the vehicle. The forks consist of struts connected through the body by torque tubes. The torque tubes can be rotated 360°, and in most angular positions of the torque tubes, the front and rear struts and wheels do not interfere with each other. The points of contact of the wheels with the terrain can thereby be made to assume many different positions with respect to the body of the vehicle. In particular, the center of gravity of the vehicle can be moved to vary the distribution of weight between the front and rear wheels. Thus, when a front wheel encounters an obstacle, the weight can be shifted to the rear wheels until the rear wheels develop

enough thrust to drive the lightly loaded front wheels over the obstacle. To ensure stability during these maneuvers, the local vertical vector is continuously monitored.

To minimize size and weight, minimal sensor and control equipment and no computing equipment are placed on the microrover itself. A commercial radio controller — of the kind used by hobbyists to control model airplanes and cars — links Go-For to an off-board computer, where the control algorithms are executed.

A video camera on the vehicle sends images to a control station, where a human supervisor chooses a sequence of paths for Go-For to traverse to reach locations of interest. For planetary exploration, a spectrometer and seismometer on the vehicle would send scientific data to the control station, and onboard tools would collect soil and rock samples. A terrestrial version could be equipped similarly to take samples in chemically and/or biologically contaminated areas.



The **Go-For** microrover is only 0.3 m high when the struts are oriented vertically.

This work was done by Brian H. Wilcox and Timothy R. Ohm of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 1*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 24]. Refer to NPO-18764.

Experimental Semiautonomous Vehicle

A robotic vehicle is used to develop navigation and obstacle-avoidance techniques.

NASA's Jet Propulsion Laboratory, Pasadena, California

A semiautonomous rover vehicle serves as a testbed for evaluation of navigation and obstacle-avoidance techniques. The vehicle is designed to traverse a variety of terrains. The concepts developed on it may be applicable to robots for service in dangerous environments (for example, those containing explosives or hazardous chemicals) as well as to robots for exploration of remote planets.

Called Robby, the vehicle is 4 m long and 2 m wide, with six 1-m-diameter wheels (see figure). It has a mass of 1,200 kg. It can surmount obstacles as large as 1½ m.

Robby is optimized for development of machine-vision-based strategies and is equipped with a complement of vision and direction sensors and image-processing computers. It is powered by a 3,500-W gasoline motor-generator that supplies 115-Vac power to onboard computers, an air conditioner, and dc power supply.

The **Front and Rear Cabs** steer and roll with respect to the centerline of the vehicle. The vehicle also pivots about a central axle, so that the wheels can comply with almost any terrain.

The vehicle includes wheel motors, a camera tilt-pan head, a gyrocompass, and a robot arm powered by the dc supply, which includes batteries that can handle surges up to 70 A at 24 V. The pan-tilt head points an array of four cameras in almost any direction with a precision of better than a tenth of a degree. The gyrocompass and inclinometers determine absolute attitude to a few tenths of a degree.

There are two onboard computers, each containing a processor and math coprocessor. One computer performs sensing, perception, and planning functions; the other performs all vehicle-actuator control functions.

A stereoscopic pair of images is generated either by the outer pair of cameras, resulting in more-accurate estimates of distances to objects in the scene, or by the inner pair of cameras, which are electronically shuttered for use while the vehicle is moving. The images are processed to produce distance and confidence (in the statistical sense) maps of points in the images.

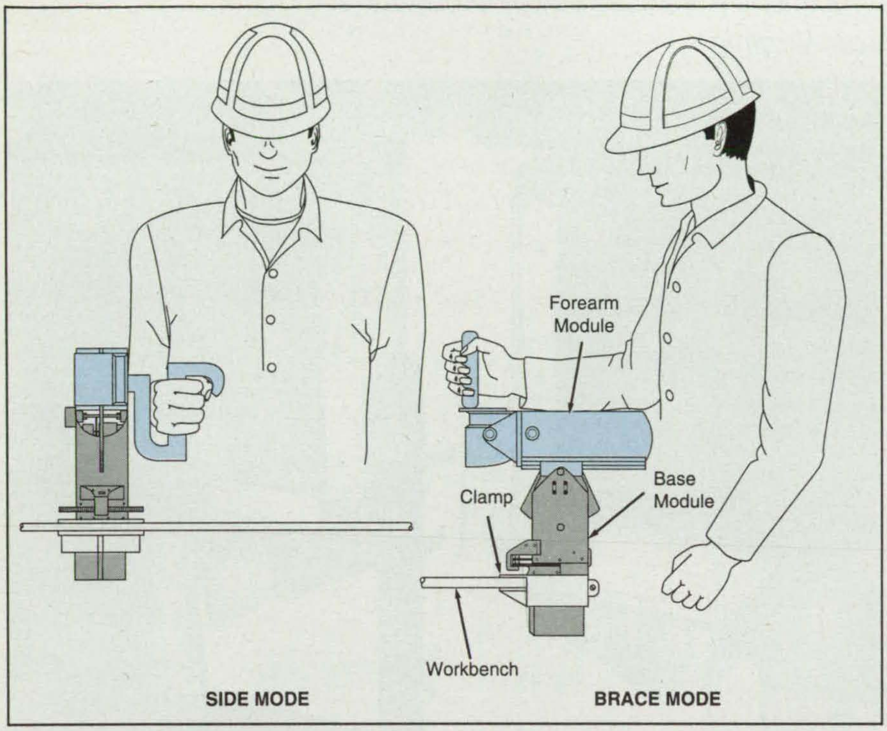
The distance maps of the local terrain are then transformed into coordinates like those of maps that would be made by observations from far overhead (e.g., orbital photography). The sparse elevation data in the local distance maps are then combined with global map information derived from real overhead photographs. The resulting combination map is used to estimate the position of the vehicle to an accuracy within 1 m. The combined data are then used to plan a safe path for the vehicle for roughly 6 to 8 m ahead. Expected roll, pitch, and articulation angles are predicted. The vehicle then traverses the path, monitoring actual pitch, roll, and articulation as it goes. When the vehicle stops, either at the end of the planned path or because it encounters an unforeseen condition, the entire perception/planning/execution process repeats.

This work was done by Brian H. Wilcox, Andrew H. Mishkin, Todd E. Litwin, Larry H. Matthies, Brian K. Cooper, Tam T. Nguyen, Erann Gat, Donald B. Gennery, Robert J. Firby, David P. Miller, John L. Loch, and Marc G. Slack of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 91*** *on the TSP Request Card. NPO-18731*

Low-Fatigue Hand Controller for Remote Manipulator

A versatile unit is designed to brace the user's arm.

Lyndon B. Johnson Space Center, Houston, Texas



The **Universal Master Controller** can be used in the brace mode, in which the user's forearm rests atop the upper (forearm) module. Alternatively, the user can manipulate the hand controller in the side mode, which gives greater latitude for motion but requires more muscular effort.

A hand controller for a remote manipulator can be operated in a brace mode, in which the user's forearm rests on a module called the "forearm module," which is attached to another module called the "base module." The user does not rely on shoulder motions or body weight to produce the necessary control force, and therefore tires less rapidly. In addition, the brace mode steadies the user's hand for precise movement under a heavy load. (In writing, one braces the forearm in much the same way to manipulate a pen or pencil.) In addition, the hand controller can be used in the side mode, in which the forearm is positioned to one side of the controller and is not braced (see figure).

The controller provides six degrees of freedom and reflects, back to the user, scaled versions of the forces experienced by the manipulator. The manipulator is designed to condense its work space into the user's natural work volume. It can be operated by both right-handed and left-handed users. It does not interfere with the user's natural movements or obstruct the user's line of sight.

The controller is compact (about the size of a workbench vise) and portable. It requires only a small area on a mounting surface. Mounting is simple; the unit is attached to the edge of a workbench or other mounting surface by use of an integral clamp.

The base module contains two revolute joints, plus a prismatic joint through which it is connected to the forearm module. The forearm module contains three revolute joints that intersect at a common point, directly below the user's wrist in the brace mode. This geometry makes remote manipulation feel more comfortable.

Each joint in each module is equipped with such safety components as power-off brakes and limit stops to protect the user against unexpected loads or sudden movements. In addition, "dead-man" switches can be incorporated to trigger software-controlled interlocks to prevent accidental or other improper operation.

This work was done by Brice MacLaren, Gary McMurray, and Harvey Lipkin of Quanta, Inc., for **Johnson Space Center**. *For further information,* ***write in 26*** *on the TSP Request Card. MSC-21832*

Casting Using a Polystyrene Pattern

A quick lost-wax technique produces inexpensive, effective wind-tunnel models.

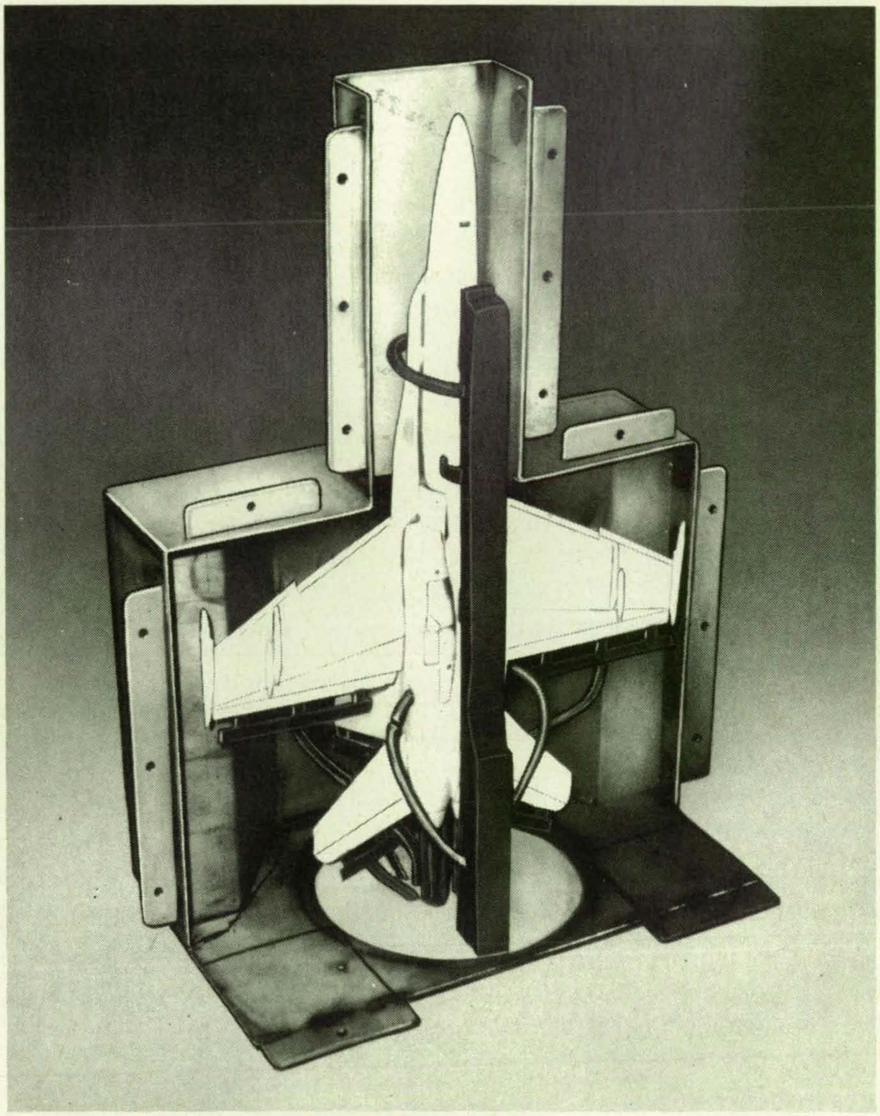
Langley Research Center, Hampton, Virginia

In the conventional lost-wax casting process for creating wind-tunnel models, at least 30 percent of the total effort is required for making the pattern, and even more effort is required if molds are to be made. This technique typically requires drawings, construction of a pattern out of wood, construction of molds, and assembly of the wax-injected parts into a complete model, all taking several weeks of work. A new technique for making metal aircraft models saves a significant amount of time and effort in comparison with the conventional lost-wax method.

In an example of the new approach, a polystyrene model was used as a pattern. Because the model was to be cast in its completed configuration, wax strips were attached to such thin sections as the wings and stabilizer to ensure flow of the molten metal. The regular lost-wax process was then followed by encasing the plastic model in a ceramic shell.

Unfortunately, a problem developed at the burn-out stage. Normally, the wax object is burned out, leaving a void in the ceramic. In this case, the filler in the polystyrene would not burn out completely and clogged the pores in the ceramic shell. The ceramic was prevented from "breathing" when the molten metal was poured, resulting in a porous casting. Even with this limitation, metal models were completed with this process in a very short time and were used to gather data in vortex studies.

This work was done by Peter Vasquez, Bengamin Guenther, Thomas Vranas, Peter Veneris, and Michael Joyner of **Langley Research Center**. *No further documentation is available.*
LAR-14214



The **Metal Wind-Tunnel Model Is Cast** by use of a polystyrene pattern in a lost-wax process.

Slip-Cast Superconductive Parts

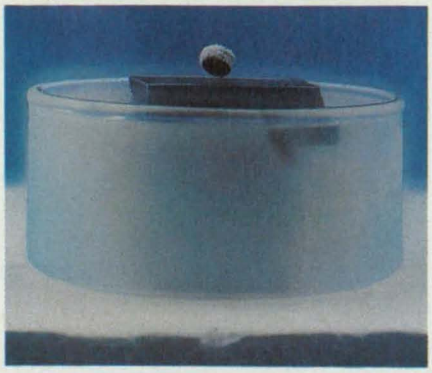
Complex shapes are fabricated without machining.

Langley Research Center, Hampton, Virginia

A nonaqueous slip-casting technique is used to form complexly shaped parts from high-temperature superconductive materials like $YBa_2Cu_3O_{7-x}$. Such parts (see figure) could be useful in motors, vibration dampers, and bearings. Machining, which introduces cracks and flaws into brittle superconductive ceramics, is made unnecessary by the nonaqueous slip-casting process.

High-temperature superconductive materials cannot be formed by conventional aqueous slip casting because they are unstable in water. In the nonaqueous slip-casting process, an organic solvent is used as the liquid medium. In addition, ceramic molds made by a lost-wax process are used instead of plaster-of-paris molds, which are used in aqueous slip casting but are impervious to organic solvents and thus cannot drain away the liquid medium. Moreover, organic-solvent-based castings do not stick to the ceramic molds as they do to plaster molds.

The ceramic powder containing the superconductive material is mixed with acetone or another organic solvent. The resulting suspension is poured into molds. After the suspension has hardened, the



A **Part Made by the Nonaqueous Slip-Casting Process** exhibits magnetic levitation, which is evidence of its superconductivity.

molds are broken to release the castings, which are then heated in an oven. The slip casting can be carried out in a magnetic field to orient the anisotropic superconductive particles in a favorable direction. The resulting parts can thereby be made to remain superconductive at greater current densities and/or greater applied magnetic fields.

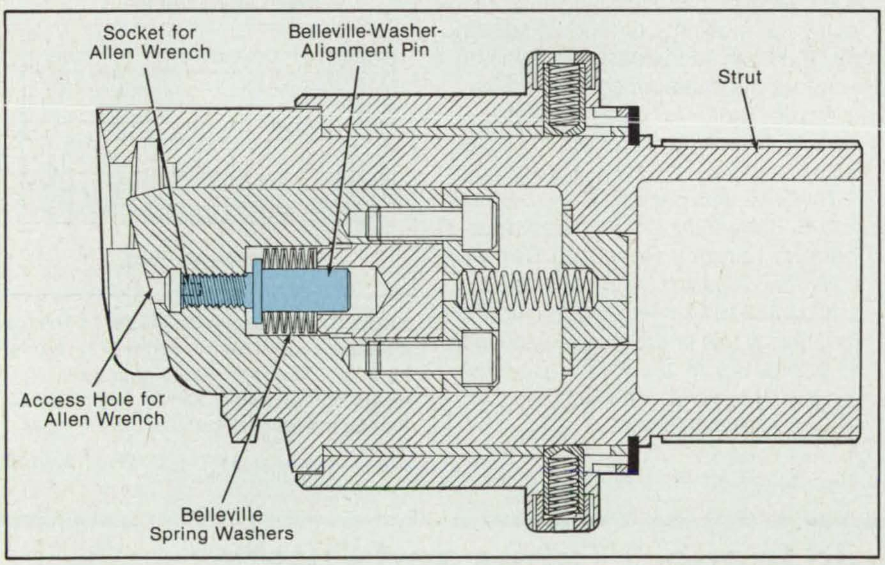
This work was done by by Stephanie A. Wise, John D. Buckley, Peter Vasquez, Gregory M. Buck, and Lana P. Hicks of **Langley Research Center** *and Matthew W. Hooker and Theodore D. Taylor of Clemson University. For further information,* ***write in 53*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquires concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 24]. Refer to LAR-14918.

Adjustable-Torque Truss-Joint Mechanism

A threaded pin is tightened or loosened; a tedious trial-and-error procedure is shortened.

Langley Research Center, Hampton, Virginia



The **Threaded Belleville-Washer-Alignment Pin** is turned, by use of an allen wrench, to adjust the compression preload on the Belleville washers and thereby adjust the joint-operating torque.

A mechanism that joins a strut and a node in a truss structure can be preloaded to a desired stress to ensure a tight, compressive fit that prevents motion of the strut during loading or vibration. The preload stress on a stack of Belleville spring washers is adjusted by tightening or loosening a threaded Belleville-washer-alignment pin. Previously, in a tedious trial-and-error procedure, the joint was assembled, tested, and disassembled if the compression of the washers did not yield the specified joint-operating torque. Belleville washers were then added or removed, and the joint was reassembled. As many as six iterations were needed to obtain the correct preload.

The mechanism includes mating conical surfaces at the end of the strut and on the node. At full engagement, an internal latch mechanism is activated, locking the parts together. The latch mechanism comprises a latch bolt, the Bel-

leville washers stacked on the threaded alignment pin (see figure), a latch plunger, and a latch retainer. Latch-retainer screws hold the latch mechanism together.

The outer end of the Belleville-washer-alignment pin contains an allen socket. The installer can insert the allen wrench in the socket through an access port. To increase or decrease the compression of the Belleville washers, the installer tightens or loosens the pin, respectively. The washer-compression force is applied through the latch mechanism to the mating surfaces of the strut and the node.

By use of the allen wrench, the operating torque on the joint can readily be adjusted (via adjustment of the compression) to 45 lb•in. (5.1 N•m). Previously, the torque was measured after the joint had been assembled. If it did not fall within 43 to 47 lb•in. (4.9 to 5.3 N•m), the joint was disassembled and a different stack of Belleville washers was installed in the latch mechanism. This procedure was not only tedious and time consuming but also potentially damaging to parts of the joint.

This work was done by Harold G. Bush of **Langley Research Center** *and Richard E. Wallsom of Lockheed Engineering & Sciences Co. For further information,* ***write in 10*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 24]. Refer to LAR-14899.

Laminates Reinforced by Short Transverse Rods

Interlaminar strengths would be increased.

Langley Research Center, Hampton, Virginia

Short transverse rods would be incorporated into laminated composite panels to increase the interlaminar (and, to some extent, the intralaminar) strengths of the panels, according to a proposal. The rods would help the panels resist delamination caused by impacts from dropped tools or, in vehicles, by debris.

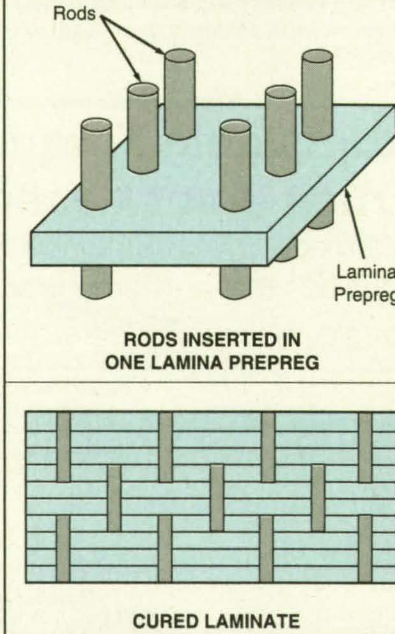
The short rods would be inserted into selected individual internal layers during preimpregnation. When the layers were stacked and heated to cure them into a laminated composite panel, the rods protruding from the selected layers would penetrate the hot, relatively soft adjacent layers (see figure). When the cure was complete and the laminate was cooled, the rods would be fixed in place and would strengthen the layer-to-layer bonds.

Layers of the rod-reinforced prepreg would be assembled into laminates by the same automated or manual layup methods used for conventional laminates. A wide variety of materials could be used for both the layers and the rods. The lengths and diameters of the rods and the insertion patterns would be chosen to suit the materials and the end uses.

This concept of reinforcement by short rods would offer advantages over current methods of increasing interlaminar and intralaminar strengths. Unlike through-the-thickness reinforcement via the established techniques of stitching and tufting, the proposed technique would not require complicated machinery and the high cost of long processing times. This technique of reinforcement would add only modestly to the cost of a laminate — about the same as compliant interlayers do. The rods could be inserted in line with prepregging and would not reduce the rate of production significantly.

This work was done by Gary L. Farley of U.S. Army Vehicle Structures Directorate at **Langley Research Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 24]. Refer to LAR-14892.



Short Rods Would Be Made To Pierce a single layer of matrix material at regular intervals. The rods would penetrate other layers during curing, although none would extend the full thickness of the laminate.

Robotic System Would Inspect Tubes and Fillets

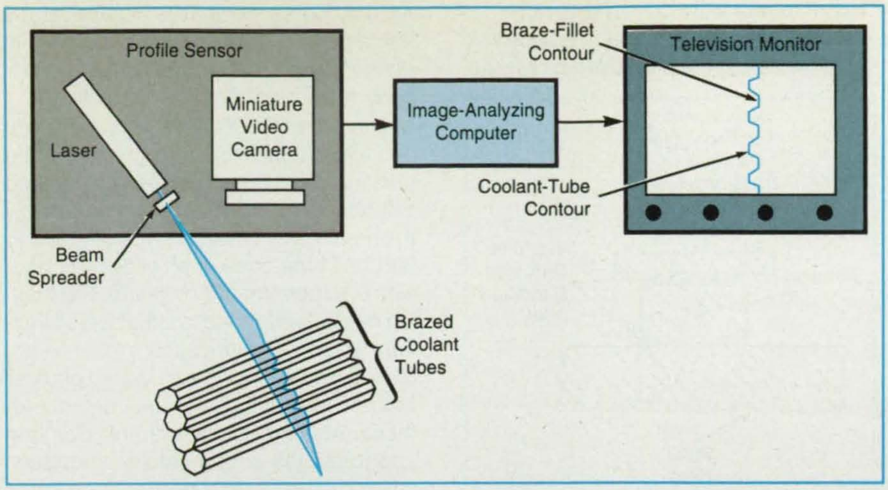
Heat exchangers and similar objects would be inspected fully and consistently.

Marshall Space Flight Center, Alabama

A proposed robotic system would inspect arrays of brazed tubes that were being fabricated for use in heat exchangers and similar objects. In the application for which the original version of the system was conceived, the arrays would contain coolant tubes to be mounted in the nozzle of the main engine of the Space Shuttle. Other versions might be used to inspect components of terrestrial heat exchangers for powerplants, vehicles, and refrigeration equipment, for example.

In the Space Shuttle application, the array of coolant tubes must be inspected for dents and scratches on the tubes, brazing alloy on the crowns of the tubes, wetting of the tubes by the brazing-alloy fillets, voids and blobs in the fillets, skulling (crust), and discoloration. In addition, the sizes of the fillets must be measured. Heretofore, the arrays of coolant tubes have been inspected manually and visually by multiple technicians. Manual and visual inspection is very tedious and time consuming. It is also highly subjective, and technicians might occasionally misinterpret what they see and/or leave some areas uninspected: consequently, the results of manual and visual inspections by different technicians can be inconsistent.

The proposed robotic inspection sys-



The **Robotic Inspection System** would scan an array of brazed coolant tubes. A computer executing image-processing algorithms would extract profiles of the tubes and braze fillets and identify flaws.

tem would provide for automated, complete, objective, and efficient inspection of the arrays of coolant tubes. The system (see figure) would include a laser and a video camera that would scan the array of tubes under computer control. The camera, the scanning robot, and an image-processing computer would be integrated into one subsystem. The output of the video camera would be digitized and fed to the image-data-processing computer, which would extract profiles of the tubes and fillets from the image data. This computer would also analyze the profiles to identify dents and scratches, brazing alloy on the crowns, wetting, voids, blobs, and skulling, and to compute the sizes of the fillets. A color version of the system could also look at oxidation and discoloration. A videotape recorder could be used to monitor the inspection process and provide a record of the work performed.

Some components and subsystems like those to be incorporated into the robotic inspection system (for example, through-the-torch-vision weld-inspection and optoelectronic profile-sensor systems) are already being used in production. Two-dimensional machine-vision systems have been used to detect some of the above-mentioned defects on coolant tubes.

This work was done by Jeffrey L. Gilbert, David A. Gutow, John E. Maslakowski, and David C. Deily of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29931

Bonding Diamond to Metal in Electronic Circuits

Electrically insulating, heat-conducting diamond supports can be bonded without incurring electrical leakage.

Lewis Research Center, Cleveland, Ohio

An improved technique for bonding diamond to metal has evolved from the older technique of soldering or brazing and is more suitable for the fabrication of delicate electronic circuits. The technique, which involves diffusion bonding, was developed to take advantage of the unique electrically insulating, heat-conducting properties of diamond, using small diamond bars as supports for slow-wave transmission-line structures in traveling-wave-tube microwave amplifiers. The diffusion-bonding technique can also be used to mount such devices as transistors and diodes that must be electrically insulated from, but thermally connected to, heat sinks.

Figure 1 illustrates the results of bonding by the older soldering or brazing technique. In this technique, one bond is formed by melting a strip of solder or brazing alloy between the diamond support and the metal contact on the component to be mounted, and the other bond is formed simultaneously by melting a similar strip between the diamond and the metallic heat sink. The molten alloy wets the diamond, forming nonreproducible fillets and creeping up the sides. The nonreproducible fillets can destroy the periodicity that is necessary in a slow-wave structure, and the coating that creeps up the sides can make the sides electrically conductive.

In the improved technique, no fillets or side coats are formed (see Figure 2) because the metal bonding strips are not melted. The strips are made of an alloy

specifically for diffusion bonding. A suitable alloy contains at least one metal (e.g., Zr, Ti, Ta, Nb, or Cr) that is active in the sense that it reacts with diamond to form an adherent carbide interface. The alloy also contains at least one metal (e.g., Cu, Au, Ag, Fe, Co, or Ni) that is inactive in the sense that it does not react chemically with diamond, and that serves as a structural body that has strength and ductility.

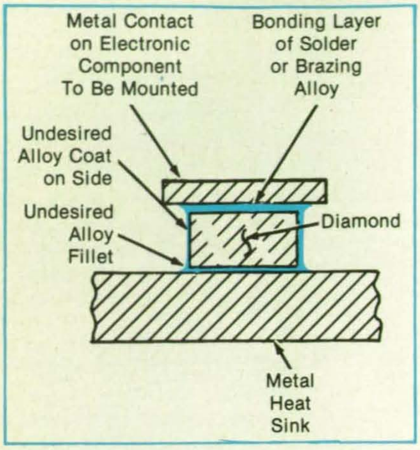


Figure 1. In **Soldering or Brazing**, the molten bonding alloy wets the diamond, forming undesired fillets and coating the sides.

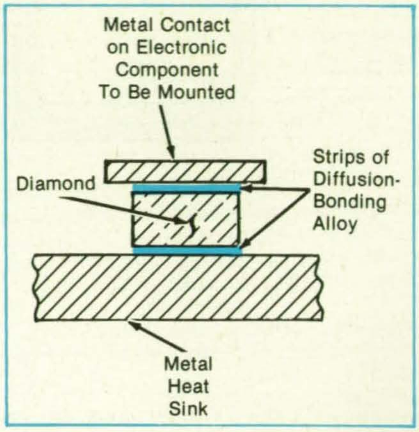


Figure 2. In **Diffusion Bonding**, the chemically active metal diffuses from within the alloy to the interfaces, where it forms bonds. The alloy is not melted.

The sandwich of metal parts, diamond, and alloy strips is clamped, typically at a pressure of 300 psi (2 MPa), and heated to the bonding temperature, which is below the melting temperature (typically, 800 to 900 °C in the case of an alloy of copper with 0.15 percent of zirconium). The heating can be performed in either a high vacuum or an inert atmosphere like helium. During the heating, the zirconium or other active metal diffuses to the contact surfaces, where it reacts with the diamond and forms the strong carbide interface.

This work was done by Andrew E. Jacquez of Varian Associates for **Lewis Research Center**. *For further information,* ***write in 73*** *on the TSP Request Card. LEW-15178*

Silicon Holder for Molecular-Beam Epitaxy

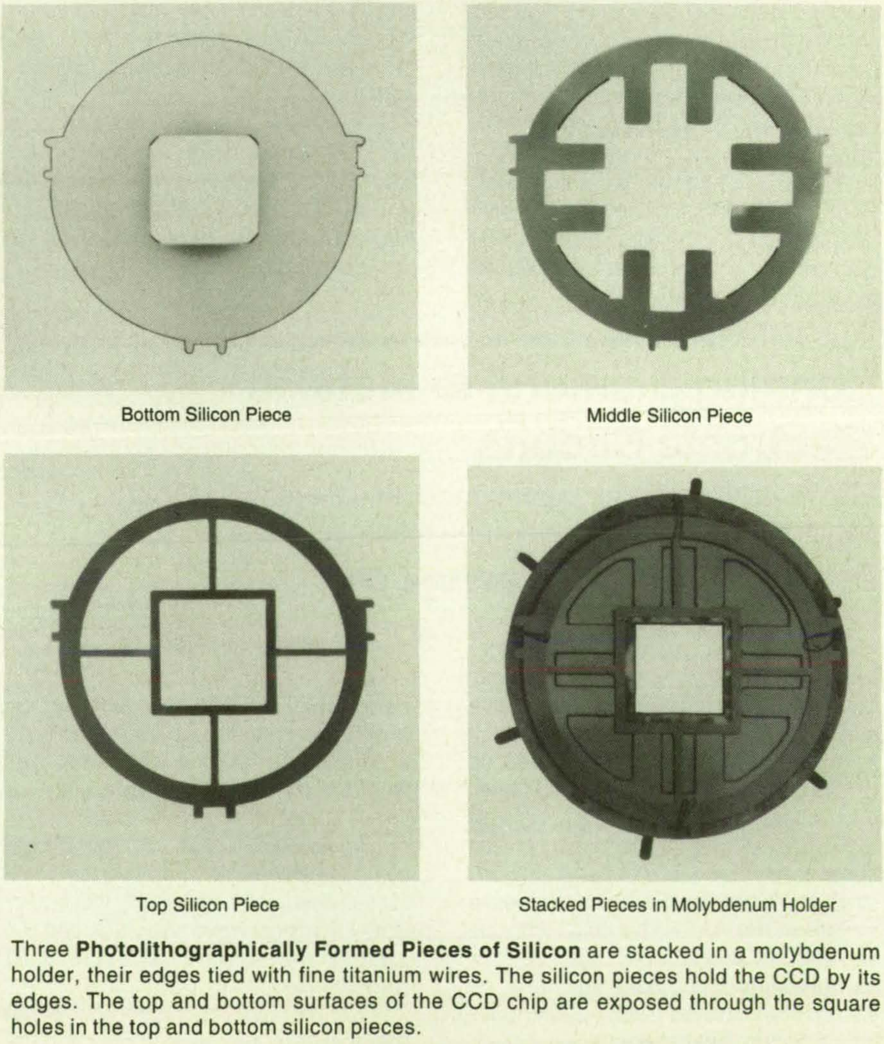
The thermal expansion of the holder matches that of the chip to be held.

NASA's Jet Propulsion Laboratory, Pasadena, California

A simple assembly of silicon wafers holds a silicon-based charge-coupled device (CCD) during postprocessing in which silicon is deposited by molecular-beam epitaxy. Previously, a holder made of molybdenum could not be used during molecular-beam epitaxy because the CCD would be damaged by local hotspots created at points of contact between the CCD and the holder.

The silicon holder, in contrast, attains temperatures similar to that of the CCD, so that hotspots are suppressed. Moreover, the coefficients of thermal expansion of the holder and CCD are equal, so that thermal stresses caused by differential thermal expansion and contraction do not develop. In addition, the silicon holder can readily be fabricated, by standard silicon processing techniques, to accommodate various CCD geometries. Unlike most materials, the silicon does not contaminate the CCD or the molecular-beam-epitaxy vacuum chamber.

The holder consists of three silicon pieces that are stacked to form a silicon cavity that encases the edges of the CCD (see figure). The bottom silicon piece contains an opening for passage of radiant heat to the CCD. The middle silicon piece centers the CCD in the stack. The top silicon piece includes a frame on four narrow cantilevers that gently press the CCD into place. The stack of three silicon pieces is mounted in a standard molybdenum holder for 2-in. (5.1-cm)-diameter silicon wafers. Four titanium wires hold the stack together at its edges.



Three **Photolithographically Formed Pieces of Silicon** are stacked in a molybdenum holder, their edges tied with fine titanium wires. The silicon pieces hold the CCD by its edges. The top and bottom surfaces of the CCD chip are exposed through the square holes in the top and bottom silicon pieces.

The silicon pieces are made from 3-in. (7.6-cm)-diameter silicon wafers. Thermal oxide layers 0.5 μm thick are first grown on the wafers, then patterns are

transferred to them by photolithography. The patterns are etched into the oxide layers by a carbon tetrafluoride plasma. An ethylene-diamine pyrocatechol solution at a temperature of 100 °C carves the photolithographically defined openings in the exposed silicon. Finally, the pieces are cleaned so that they do not outgas in the ultrahigh vacuum of molecular-beam epitaxy.

This work was done by Michael E. Hoenk, Paula J. Grunthaner, and Frank J. Grunthaner of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 21*** *on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

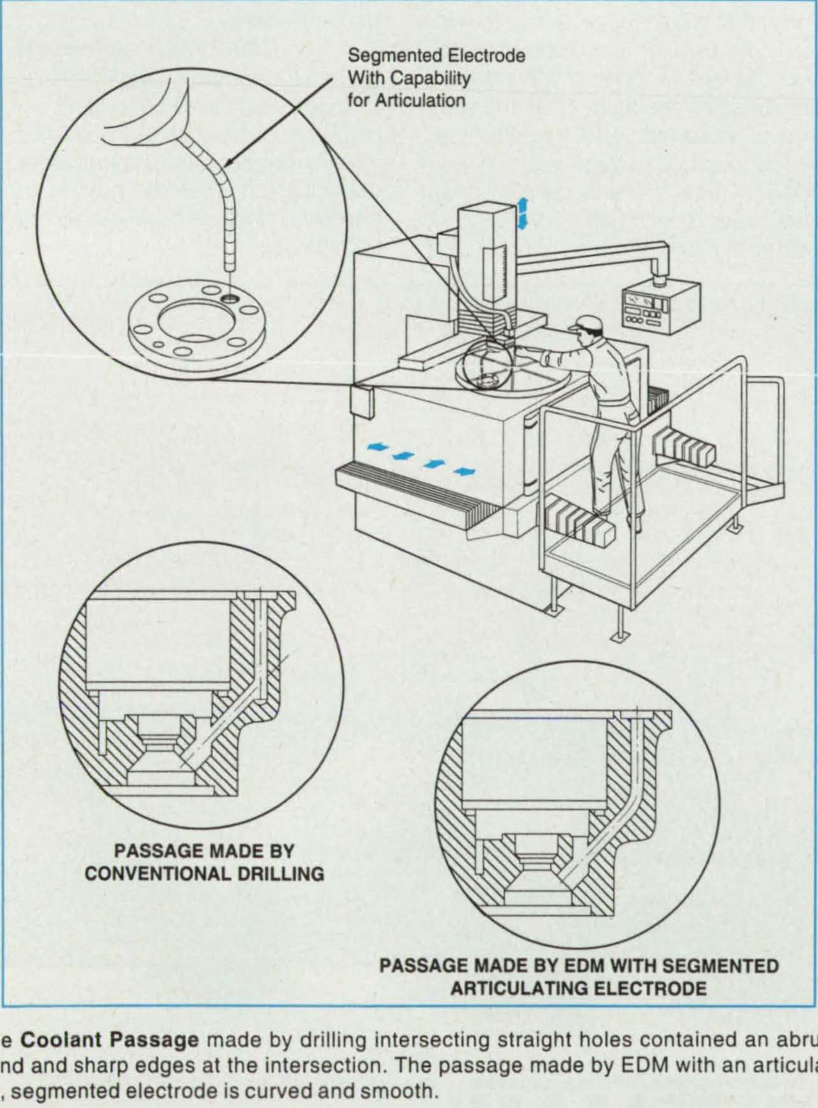
William T. Callaghan
Technology Commercialization
(M/S 301-350)
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109

Refer to NPO-18687, volume and number of this NASA Tech Briefs *issue, and the page number.*

Electrical-Discharge Machining of Curved Passages

A curved passage can be made in a single-step process.

Marshall Space Flight Center, Alabama



The **Coolant Passage** made by drilling intersecting straight holes contained an abrupt bend and sharp edges at the intersection. The passage made by EDM with an articulated, segmented electrode is curved and smooth.

Electrical-discharge machining (EDM) can be used to cut a deep hole with bends; for example, to make a coolant passage (see figure). This EDM process replaces conventional drilling of intersecting straight-hole segments, which had to be done in several steps from opposite faces of a part. Drill bits often broke and were difficult to extract. Moreover, the bend at the intersection of two drilled straight holes

had sharp edges that had to be deburred by a difficult and tedious manual procedure. Even after deburring, the sharp bend produced undesirable turbulence when coolant liquid flowed through it. Drilling also produced particles that could clog ducts, jam pumps, and/or damage other equipment.

The EDM process is done with an articulating segmented electrode. Originally straight, the electrode is curved as it penetrates the part, forming a long, smoothly curving hole. After the hole has been cut, it is honed with a slurry to remove the thin layer of recast metal created by EDM. Breakage of tools, hand deburring, and drilling debris are eliminated.

This work was done by Kamal S. Guirguis of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29909

Automated Cutting and Drilling of Composite Parts

Machine tools and controls would obviate tedious manual operations.

Marshall Space Flight Center, Alabama

A proposed automated system would precisely cut and drill large, odd-shaped parts made of composite materials. The system was conceived for manufacturing lightweight composite parts to replace heavier parts in the Space Shuttle and would be useful in making large composite parts for other applications as well. Heretofore, such parts have been manufactured by manual procedures.

In the manual method, once a part has been cured, trim lines are marked on it to identify the final edges. Rough cuts are made close to the trim lines by a bandsaw or hand-held jigsaw with a diamond-impregnated blade. Then a hand-held grinder is used to remove most of the remaining trim material. Finally, the part is sanded manually to produce a finished edge.

Bushings are clamped on the opposite surfaces at each drill site to prevent delamination. Then holes are drilled in the part, one by one, for later use in the assembly process. Drill feed rates are controlled to prevent excessive heating. The drilling process is slow and tedious.

The automated system would include a robot that would locate the part to be machined, position the cutter, and position the drill. A gantry-type robot is best suited for the task; it has the wide range of movement and rigid structure needed to process large parts. It also positions tools more accurately than do robots of other types.

Either a machine vision system or a laser rangefinder would be used to locate the part to be machined. A machine vision system, although slightly more expensive, would identify part locations faster.

A water-jet cutter, held by the robot, would cut and finish the part. Although such a cutter requires a costly pump that supplies a pressure of 60 kpsi (about 400 MPa), it is versatile and well suited to composites.

A complete drilling system can be bought for about $70,000 (1991 prices) — a cost that could be justified only for high-volume production. For small quantities, a simpler machine tool would be developed. It would do precise drilling and would include hardware to prevent delamination.

An automatic tool changer would save time when tools are to be changed on the robot. The tool changer would also extend the lifetime of mounting hardware.

At least three desktop computers would be needed — one for overall coordination, one for the robot, and one for the water-jet cutter and drill. Control and coordination software would have to be developed. Easy-to-use, menu-driven software would be provided for each computer. Software for off-line programming of the robot and tools is already available.

This work was done by Charles W. Warren of the University of Alabama for **Marshall Space Flight Center**. *For further information,* ***write in 71*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 24]. Refer to MFS-27282.

Microlabels for Auto Parts

Compressed symbols would fully characterize each part by type and manufacturing history.

Marshall Space Flight Center, Alabama

A proposed method of unique labeling and identification of automotive parts would greatly simplify recall campaigns and reduce the effort and expense associated with them. At present, there is little information for deciding which automobiles are affected by a defect. This uncertainty leads manufacturers to call in thousands of vehicles unnecessarily for inspections. With the proposed method of labeling, manufacturers could notify only those owners whose cars need repairs or modifications.

The labeling and identification scheme involves the use of compressed symbology, in which all the data a manufacturer needs to establish the pedigree of a part are contained within a small checkerboard square, etched by laser or otherwise applied to the part. For example, the data could identify the manufacturer, the lot number of the parent material from which the part was made, the date of manufacture, design changes, serial number, and special processes to which the part was subjected in manufacturing.

All the data needed to determine, accurately and automatically, the extent of a needed recall of vehicles can be contained in this label or in a keyed data base, either or both of which would provide detailed information about every part in every automobile sold or in operation. Thus, when a part or a series of parts failed because of a design or manufacturing defect, the label(s) of the part(s) would be examined. Only a few cars may be found from the data base to have the same pedigree, and only tens or hundreds, instead of thousands, may have to be recalled to dealers for inspection. The dealers would check the identification marks on the components to ensure that they match the data in the manufacturer's records. Similar compressed symbology is being developed for possible use on spacecraft.

This work was done by John P. Ash of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-28716

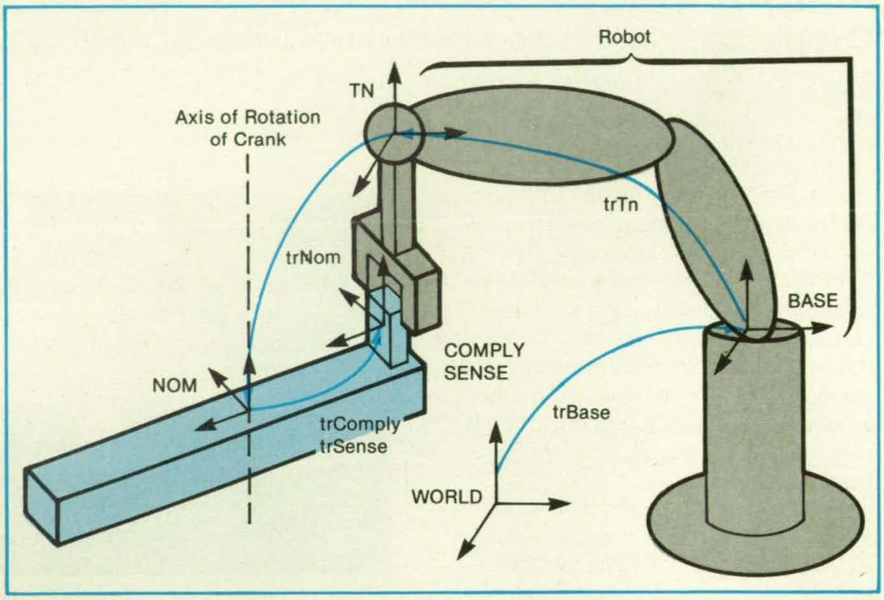
Mathematics and Information Sciences

A Generalized-Compliant-Motion Primitive

Many different motions can be commanded by specifying parameters.

NASA's Jet Propulsion Laboratory, Pasadena, California

A computer program that bridges the gap between planning and execution of compliant robotic motions has been developed and installed in the control system of a telerobot at NASA's Jet Propulsion Laboratory. The program, called the "generalized-compliant-motion primitive," is one of several task-execution-primitive computer programs, which receive commands from higher-level task-planning programs and execute those commands by generating the required trajectories and applying the appropriate control laws.



Turning a Crank is one of several tasks that involve compliant motion of a robot. The items identified in upper-case letters are coordinate frames used in the motion-control computations. The labels that include the prefix "tr" denote transformations between coordinate frames.

The program comprises four parts that correspond to nominal motion, compliant motion, ending motion, and monitoring, respectively. Nominal motion is motion of the robot along the specified trajectory. Compliant motion is perturbation of the nominal motion due to sensory inputs; e.g., force control, teleoperation, and joint and Cartesian space virtual forces. Ending motion begins at the end of nominal motion and continues during a specified time or until specified ending conditions (e.g., attainment of a desired position and contact force) are satisfied. Monitoring involves verifying that the commanded task or motion is being executed safely and stopping the motion if an anomalous condition (e.g., excessive contact force or motion beyond a limit position) is detected.

Commands from higher-level programs are received in the form of parameters: the generalized-compliant-motion-primitive computer program provides a rich set of such input parameters, which specify the details of a variety of compliant-motion tasks — for example, opening a door, turning a crank (see figure), seating and turning a bolt, pushing, sliding, leveling, and insertion or removal of a pin. The parameterization scheme provides for general compliant motion, nominal motion, force control, and sensing separate nominal-motion, compliant-motion, and sensor reference frames for control and safety monitoring; combined position and force control in all six degrees of freedom of the control reference frame; and testing for, motions in, and responses to, ending conditions.

The program implements a split-rate force-control technique. Force and torque data are read from a six-axis force sensor. Contact forces are computed by subtracting, from sensed forces, the contributions of the weight of the manipulated object in the given robot pose. The coordinate frames used in these and other computations are Cartesian. The program is written in the C language, with utilities from the RCCL robot programming and control software system.

This work was done by Paul G. Backes of Caltech for **NASA's Jet Propulsion Laboratory**. *For further informaton,* ***write in 55*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 24]. Refer to NPO-18134

Algorithms for Detection of Correlation Spots

These algorithms function in the presence of noise and can be executed rapidly.

NASA's Jet Propulsion Laboratory, Pasadena, California

Three algorithms provide for improved postprocessing of the outputs of optical correlators that are based on binary phase-only filters. These algorithms detect correlation spots; that is, peaks in the local intensities of the output correlation images. The algorithms are based partly on previously observed characteristics of typical noisy correlation images and are designed to perform better than do older peak-detection algorithms, which are inadequate in the presence of noise. Moreover, the present algorithms are simple enough to be executable in real time on modern digital processors.

The first algorithm starts processing the correlation-image data while those data are being fed out of a video camera and are being digitized for subsequent analysis. First, local peaks are identified by detecting changes in the slopes of intensity-vs.-position data at intensities above a specified threshold. All peaks that lie within a distance of $\pm\varepsilon$

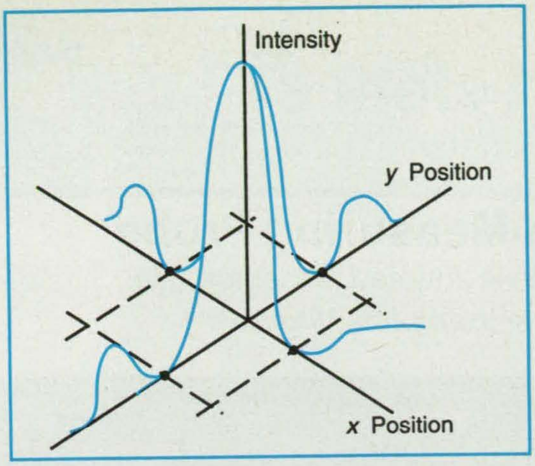
pixels (where ε is a predetermined tolerance) are deemed to belong to the same cluster, and the cluster is deemed to be represented by the highest peak in it. Then the correlation image is segmented, as shown in the figure, by use of those four minimums of each representative peak that lie on the principal Cartesian coordinate axes. Next, each segment is binarized by use of the half peak intensity as the cutoff level.

The areas of the binarized images of the representative peaks, the moments and products of inertia of these images in the original Cartesian coordinates, and the ratios between the minimum and maximum possible moments of inertia in suitably rotated Cartesian coordinates are then computed. For each representative peak, these quantities can be analyzed to determine whether they indicate that the spot is narrow and elliptical, as true correlation spots have generally been observed to be.

The second algorithm involves the convolution of the correlation image with a small-window two-dimensional impulse-response function (convolution kernel) followed by a threshold operation in which negative values of the convolution integral are set to zero. This algorithm intensifies correlation peaks and suppresses noise. The impulse-response function can be binarized; this not only facilitates rapid processing but also makes the algorithm insensitive to fluctuations in the intensity of the correlation image.

The third algorithm affects the generation as well as the postprocessing of the correlation image. It involves the use of multiple-spot correlation patterns to distinguish between speckle-noise spots and correlation spots, which can sometimes resemble each other. First, one generates a binary phase-only filter from a reference image that contains multiple, specifically displaced identical objects. In the absence of noise, such a reference image would result in a correlation image that contained a definite, discrete pattern of multiple correlation spots. By comparing the real, noise-corrupted correlation image with the expected pattern of multiple correlation spots, it should be possible to identify the correlation spots on the random background pattern of speckle-noise spots.

This work was done by Marija S. Scholl and Suraphol Udomkesmalee of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 92*** *on the TSP Request Card. NPO-18446*

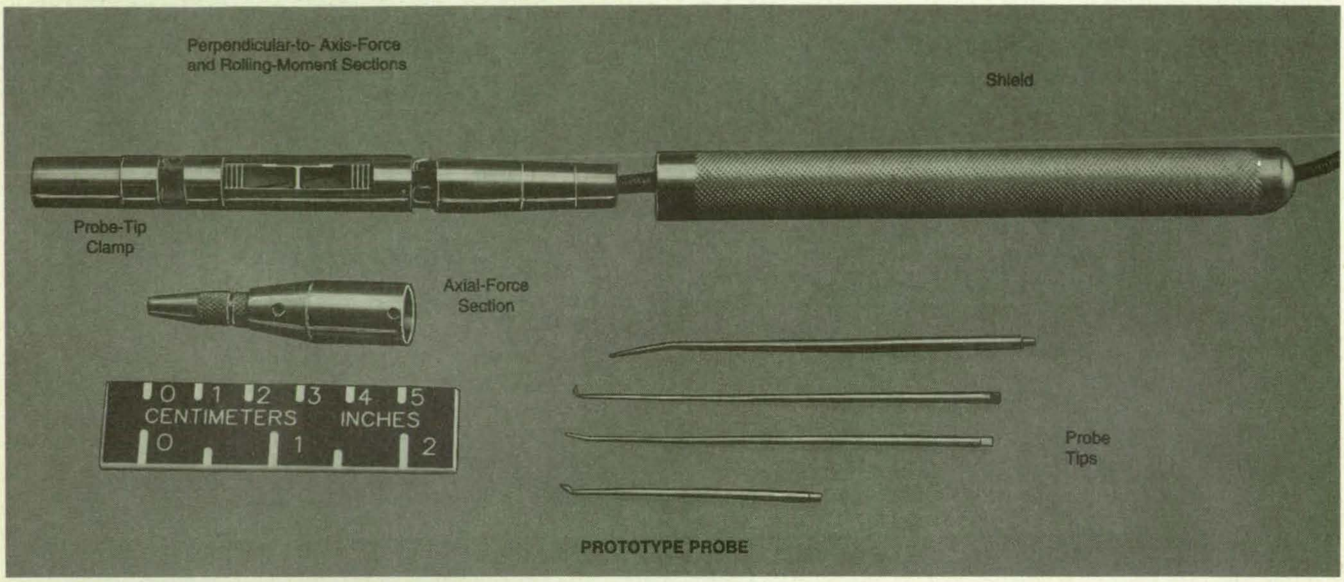


A Correlation Peak is Segmented, then binarized for analysis of its width and ellipticity. If the peak is narrow and elliptical, it is likely to be a correlation peak.

Surgical Force-Measuring Probe

An aerodynamic balance is adapted to medical use.

Langley Research Center, Hampton, Virginia



The **Lightweight, Pen-Shaped Probe** can be easily held by a surgeon. The cable feeds output signals to processing circuitry.

An electromechanical probe measures forces and moments applied to human tissue during surgery. The measurements can be used to document optimum forces and moments for surgical research and training. In neurosurgical research, for example, measurements can be correlated with monitored responses of nerves. In training, students can learn procedures by emulating the forces used by experienced surgeons.

The probe (see figure) includes a pen-shaped housing that contains an aerodynamic balance like the balances used in wind-tunnel experiments. The balance produces electrical signals proportional to the forces and moments on the tip of the instrument. A signal conditioner amplifies and filters the signals, and a desktop computer acquires, processes, and displays them. A variety of surgical tips can be attached to the instrument.

The aerodynamic balance contains strain gauges that measure the forces and moments along three orthogonal axes. The aerodynamic balance in the prototype probe is oversized, with respect to loads, for surgical applications: it can withstand forces of 30 lb (130 N) along one direction perpendicular to its axis, 10 lb (45 N) along its axis, and 20 lb (89 N) along the third orthogonal direction; and moments of 40 lb•in. (4.5 N•m) in pitch, 10 lb•in. (1.1 N•m) in roll, and 20 lb•in. (2.3 N•m) in yaw. For the practical version, design loads will be much lighter: a force of 1 lb (4.4 N) and a moment of 2 lb•in. (0.23 N•m) are expected to be adequate. The prototype measures 0.5 in. (1.3 cm) in diameter and 7 in. (17.8 cm) in length, exclusive of the probe tip. The production version of the instrument will be about 1 in. (2.5 cm) shorter.

The strain gauges in the production version are to be mounted on beams made of 7075-T6 aluminum, a lightweight, high-strength alloy chosen because the device must withstand the high stresses needed for acceptable sensitivity. The beams are to be fabricated by electrical-discharge machining from a single piece of aluminum to eliminate mechanical joints and thereby increase accuracy. Critical dimensions must be machined to a tolerance of only ±0.0005 in. (±13 μm). Mechanical stops in the form of adjustable setscrews will probably be used to prevent overloading of the beams and strain gauges. An electronic overload alarm may also be included.

The probe is calibrated by the application of deadweight loads similar to those that will be applied to the probe tips. Incremental loads are applied for each component of force and moment while the electrical outputs of the instrument are recorded by a data-acquisition system that acts as a signal and control interface between the instrument and the desktop computer. Interaction effects among the axes are expected to be negligible in the production version of the instrument.

This work was done by Ping Tcheng, Paul W. Roberts, and Charles E. Scott of **Langley Research Center**. *For further information,* ***write in 87*** *on the TSP Request Card. LAR-14836*

Books & Reports

These reports, studies and handbooks are available from NASA as Technical Support Packages (TSPs when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Materials

Hot Deformation of Si_3N_4 Doped With Sc_2O_3

A report describes the preparation, microstructural properties, and high-temperature deformation behavior of Si_3N_4 doped with Sc_2O_3. Powders of Si_3N_4 with small additions of Sc_2O_3 can be sintered under nitrogen overpressures to full density; expensive hot pressing or hot isostatic pressing is not necessary to attain full density. Test of bars of Si_3N_4 doped with Sc_2O_3 indicate relatively high strengths at high temperatures and excellent time-dependent strength properties. These attributes make such compositions potentially useful for the fabrication of hot-section components of automotive gas-turbine engines.

This work was done by Deock-Soo Cheong of National Research Council (NRC) and William A. Sanders of **Lewis Research Center**. *Further information may be found in NASA TM-103239 [N90-28740], "High-Temperature Deformation and Microstructural Analysis for Si_3N_4-Sc_2O_3."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. LEW-15301

Materials

Test of Protective Coatings on Carbon Steel

A report describes the results of tests in which carbon-steel panels were coated with one-or two-component solvent-based inorganic zinc primers and top-coated with an inorganic topcoat or any of various organic topcoats, then placed on outdoor racks at the beach at Kennedy Space Center for 5 years. Also, from time to time, a slurry of Al_2O_3 in a 10-percent HCl solution was applied to some of the panels to simulate the corrosive effect of effluent from solid-fuel rocket booster engines.

Observation of the conditions of the panels exposed to the normal beach environment led to the following conclusions:

Seventeen commercial two-component inorganic zinc coating systems continued to perform acceptably at 5 years, whereas the two single-component organic-zinc-rich products performed poorly.

In general, panels with epoxy/polyurethane topcoats continued to deteriorate much faster than did panels that were coated only with zinc primer, although a few manufacturers' topcoats performed well. The following conclusions were drawn from observation of the conditions of the panels exposed periodically to the acidic slurry:

These panels deteriorated much faster than did the panels exposed to the normal beach environment.

High-build (designed to be applied relatively thickly) organic topcoats generally performed better than did thin-film organic

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topcoats.

Panels coated with inorganic topcoat performed much better than did the organic-topcoated panels.

This work was done by Louis MacDowell of **Kennedy Space Center**. *For further information,* ***write in 35*** *on the TSP Request Card. KSC-11595*

Machinery

Life-Support-System Analyzer

A paper describes a software system, called Generic Modular Flow Schematic (GMFS), developed for use in the synthesis, mathematical modeling, and analysis of life-support systems aboard spacecraft, ranging from simple open-loop configurations to complex closed-loop ones. GMFS can also compare alternative systems.

GMFS computes flows of materials, heat, and power in every stream of each subsystem of a life-support system. It integrates subsystems hierarchically and modularly. This organization of GMFS enables the tracing, into subsystems and functional elements, of factors that influence the behavior of the system. Traceability is useful for comparing systems or technologies.

This work was done by Panchalam K. Seshan, Joseph F. Ferrall, and Naresh K. Rohatgi of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Generic Modular Flow Schematic (GMFS) for Physical-Chemical Life Support Systems,"* ***write in 67*** *on the TSP Request Card. NPO-18612*

Mechanics

Measuring Fluctuating Pressures With Recessed Gauges

A report discusses the use of pressure gauges mounted in recesses in the interior wall of a model scramjet engine. The report is untitled and consists of a brief memorandum plus excerpts from NASA Technical Paper 3189, "Unsteady Pressure Loads in a Generic High-Speed Engine Model." The report focuses mainly on factors that affect the accuracy of the gauge readings.

This work was done by Tony L. Parrott of **Langley Research Center** *and Michael G. Jones of Lockheed Engineering & Sciences Co. To obtain a copy of the report,* ***write in 89*** *on the TSP Request Card. LAR-15043*

Mechanics

Study of Active Vibration Isolators

A report presents a study of single-link vibration-isolating active suspensions. Suspensions of this type could be used, for example, to suppress vibrations in structures or to protect delicate scientific instruments from vibrations generated by nearby machinery. In this study, the suspensions are analyzed in terms of mechanical impedance, which is analogous to electrical impedance: the mechanical impedance at a given driving point is the Laplace-transform transfer function that represents the ratio between the velocity and the force applied at that point, the force is analogous to voltage. For example, the mechanical impedance of a point mass, M, is simply 1/Ms, where s is the

Laplace-transform complex frequency.

This work was done by Boris J. Lurie, James L. Fanson, and Robert A. Laskin of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Active Suspensions for Vibration Isolation,"* ***write in 48*** *on the TSP Request Card.* NPO-18571

Mechanics

Recursive Linearization of Dynamical Models of Manipulators

A report shows how the spatial-operator algebra developed by the authors is used to derive linearized mathematical models of the dynamics of robotic manipulators. The spatial-operator algebra is a theoretical framework for the mathematical modeling and analysis of the dynamics of robotic manipulators. Aspects of the spatial-operator algebra have been described in several previous articles in *NASA Tech Briefs*, including (but not limited to) "Robot Control Based on Spatial-Operator Algebra" (NPO-17918), Vol. 16, No. 9 (September 1992), page 115; "Unified Formulation of Dynamics of Robot Arms" (NPO-18040), Vol. 16, No. 2 (February 1992), page 95; and "Spatial-Operator Algebra for Robotic Manipulators" (NPO-17770), Vol. 15, No. 8 (August 1991), page 88.

This work was done by Abhinandan Jain and Guillermo Rodriguez of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Recursive Linearization of Manipulator Dynamics Models,"* ***write in 14*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 24.] Refer to NPO-18500.

Mechanics

Longevity of Dry Film Lubricants

A report describes an evaluation of dry film lubricants that are candidates for use in rotary joints of the proposed Space Station. The study included experiments and theoretical analyses that focused on the longevity of sputtered molybdenum disulfide films and ion-plated lead films under conditions that partially simulate rolling contact.

This work was done by J.W. Kannel and R.D. Stockwell of Battelle Co. for **Marshall Space Flight Center**. *To obtain a copy of the report, "Lubricant Evaluation of Alpha and Beta Joints,"* ***write in 56*** *on the TSP Request Card.* MFS-27284

Mechanics

Algorithms for Natural-Frequency Design of Structures

A report presents the theoretical foundations of some of the algorithms implemented by the JPL-IDEAS computer program. JPL-IDEAS performs finite-element analysis of vibrational modes of a structure composed of bar and/or plate members,

and chooses the design variables (the cross-sectional dimensions of the structural members) to minimize the weight of the structure, subject to constraints of minimum acceptable natural frequencies of specified modes. JPL-IDEAS includes special features for the analysis and design of microwave antennas and associated structural components.

This work was done by Roy Levy of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Algorithms for Structural Natural Frequency Design,"* ***write in 78*** *on the TSP Request Card. NPO-18774*

Machinery

Comparison of Telerobot Control Modes

A report presents an evaluation of three different modes of telerobot control:

- Teleoperation with position control only,
- Teleoperation with force reflection, and
- Teleoperation with shared control, in which the operator controls some elements of a task (typically, position of the manipulator), while an autonomous system controls other elements of the task (typically, force and torque).

The evaluation involved experiments in which nine trained operators used a telerobot system to perform tasks of increasing difficulty — removal and insertion of an electrical connector, removal and insertion of an orbital replacement unit, and removal and insertion of an electronic-circuit board in an electronic chassis.

The report concludes, on the basis of preliminary data, that use of force reflection or shared control definitely improves the performance of the telerobotic system over that attainable with simple manual position control. These more-advanced control modes save time, reduce wear from excessive forces, and reduce numbers of operator errors.

This work was done by Wayne F. Zimmerman, Paul G. Backes, and Gregory S. Chirikjian of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Telerobot Control Mode Performance Assessment,"* ***write in 98*** *on the TSP Request Card. NPO-18844.*

Machinery

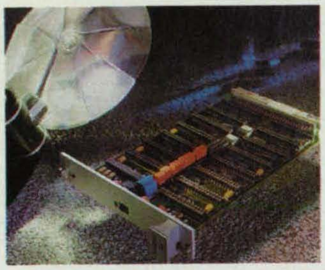
Active Suppression of Vibrations in Rotating Machinery

A NASA technical memorandum discusses problems that arise in the application of advanced methods of active control to suppress vibrations in large turbines and other rotating machinery. Researchers and industrial designers are resorting increasingly to active control because passive damping alone is often not enough to meet increasing demands for higher rotational frequencies, greater reliability, reduced noise, greater longevity, and safety.

This work was done by Heinz Ulbrich of National Research Council for **Lewis Research Center**. *Further information may be found in NASA TM-102368 (N-90-22703), "Elements of Active Vibration Control for Rotating Machinery."*

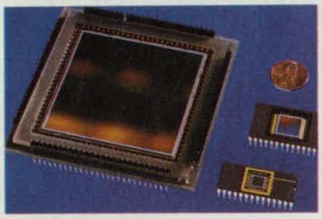
Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. LEW-15382.

New on the Market



A **nonvolatile memory board** that fits any VMEbus system has been introduced by PEP Modular Computers, Pittsburgh, PA. The 100 x 160 mm VMEM-S2 achieves up to 8 MB and can replace rotating storage for environmentally difficult applications. The board's 16 32-pin sockets are grouped in two independent banks, enabling combinations such a EPROM or Flash and SRAM. Several VMEM-S2s can be used simultaneously in a single system to achieve up to 64 MB.

For More Information Write In No. 701

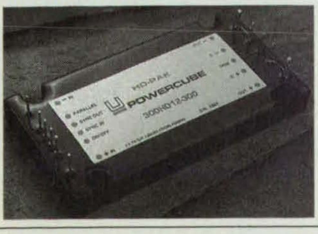


DALSA Inc., Waterloo, ONT, has produced the world's largest **image sensor**. The 26-million-pixel CCD (charge coupled device) has demonstrated wafer scale integration with an active area of 2.5" x 2.5". Developed for such applications as still photography, astronomy, and computer vision, the device has 26,214,400 active pixels arranged in a 5120 x 5120 grid.

For More Information Write In No. 704

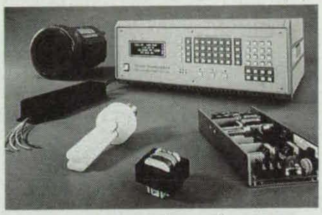
Powercube Corp., Billerica, MA, has introduced the high-density HD-PAK™ **DC/DC converters** that provide 300 W output at 54 W/in³ in an industry-standard package (4.6" x 2.4" x 0.5"). Operating at a 350 kHz fixed frequency, the new converter is available in 2.6, 3.3, 5, 12, 15, 24, 28, and 48 V regulated outputs. Features include low output ripple, remote sensing and shutdown, overvoltage protection, and synchronization from an internal and external source.

For More Information Write In No. 702



The latest version of CADDS®5 **parametric design software** from Computervision Corp., Bedford, MA, is available on HP Apollo 9000 series 700 workstations. The mechanical design automation package enables engineers to capture design concepts electronically, share ideas, and predict the behavior of products before they are manufactured.

For More Information Write In No. 706

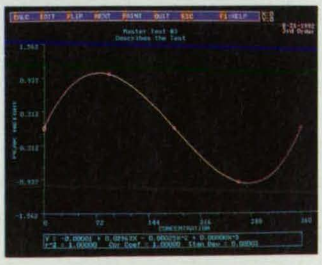


A new **power analyzer** from Xitron Technologies, San Diego, CA, employs six high-speed 24-bit digital signal processors to deliver performance improvements in bandwidth (DC, 0.01 Hz to 500 kHz), accuracy (0.05% basic accuracy), and speed (all parameters calculated in under 10 ms). The model 2503 A provides three fully-independent and isolated input channels, each capable of handling up to 3000 volts and currents of up to 100 A.

For More Information Write In No. 700

DiskMizer, a **data compression utility** that doubles the capacity of VAX hard disks, has been released by Intersecting Concepts, Agoura Hills, CA. The software uses patented compression technology to create one or more new "Files-11" volumes to store data in compressed format. Accessible as any other Files-11 volume, the DiskMizer volumes retain the benefits of the VMS file system and can be used for security and data isolation.

For More Information Write In No. 703

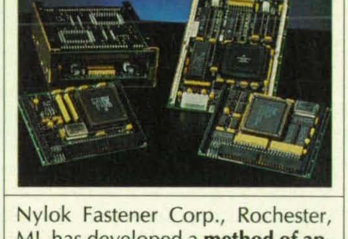


Omega Engineering Inc., Stamford, CT, has introduced CurveFit, **software that produces standard curves and residual plots instantly**, with unknowns calculated automatically. The easy-to-use program performs transformations of both X and Y axes, and can fit data with linear, cubic spline, point-to-point, polynomial squares up to fourth order, and user-modified functions.

For More Information Write In No. 705

New on the Market

The **SCSI Expander**, released by ATTO Technology Inc., Amherst, NY, increases to 49 the number of devices that can be supported from a single SCSI host adapter. Systems requiring vast amounts of data storage at peak performance levels—imagers, database servers, CD-ROM libraries, digital video, and disk arrays—now can support hundreds of gigabytes of on-line storage.
For More Information Write In No. 710



Nylok Fastener Corp., Rochester, MI, has developed a **method of applying powder compounds to fastener threads** that protects against weld-spatter, eliminates capping and plugging, and improves masking capabilities. Designed for use with corrosion-resistant electrodeposited paints, primers, and coatings, the NYCOTE® process prevents the adhesion of coatings that can fill threads and interfere with nut and bolt assembly and clamp loading.
For More Information Write In No. 707

The IL series of industrial **power supplies** from Arnold Magnetics, Camarillo, CA, offers 115/230 VAC ±20% single phase or 48 VDC ±24%. Features include input/output noise to MIL-STD-461, 20 ms hold-up time, triple output (+5 V at 10 A, +15 V at 3 A, and -15 V at 3 A), 85%+ efficiency, and 40-year life.
For More Information Write In No. 709

The first **real-time workgroup CAD/GIS system** with open system support is available from Pesus Group Inc., Lawrence, NY. The easy-to-use AEGIS (Architectural/Engineering/Geographical Information System) features intelligent walls, spaces, and objects; collaborative computing with instant updates; and "Hyperlinks" for easy transfer of data/graphics between computers.
For More Information Write In No. 711

Enterprise Software Products Inc., Harleysville, PA, has released an update of FEMAP, its fully-interactive **finite element modeling and postprocessing software**. Features include 3D CAD geometry created in FEMAP or imported through IGES or DXF files; automatic mesh generation; and support for isotropic, orthotropic, and anisotropic materials. FEMAP can read, write, and postprocess data from ALGOR, ANSYS, COSMOS/M, MSC/PAL2, PATRAN, STARDYNE, MSC/NASTRAN, PC/NASTRAN, and UAI/NASTRAN.
For More Information Write In No. 712

A wide range of **optical cements and adhesives** is available from Summers Laboratories, Fort Washington, PA. Product lines include UV curing and two-component adhesives as well as cement room supplies, mixing kits, and a lens coating hardness tester kit.
For More Information Write In No. 713

Steel-on-steel spherical **plain bearings** made from high-strength carbon chromium steel are available in a multi-lube groove design from SKF Plain Bearings Co., King of Prussia, PA. Compared to the circumferential groove design used on standard radial bearings, the new bearings offer increased service life and contamination resistance, and can be re-lubricated while under high loads at extended intervals.
For More Information Write In No. 708

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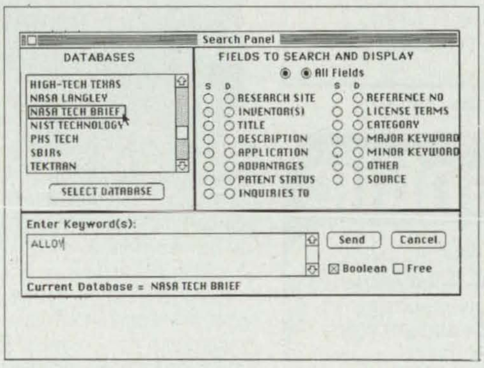

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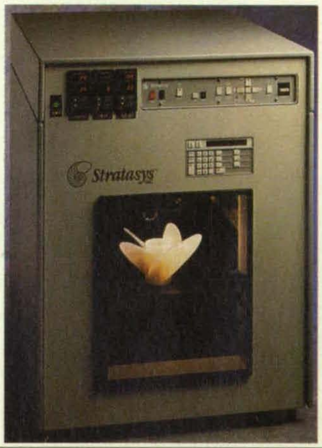
New on the Market

Stratasys Inc., Minneapolis, MN, has announced the FDM® 1000, a $50,000 **rapid prototyping system** that builds models quickly and accurately. The system is supported by Silicon Graphics IRIS workstations and operates with Stratasys' QuickSlice™ software. It uses the patented Fused Deposition Modeling process to form prototypes through an extrusion and lamination procedure, building the model layer upon layer within a 10" x 10" x 10" working envelope.

For More Information Write In No. 714

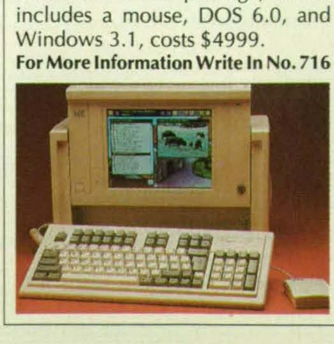


Microsoft Corp., Redmond, WA, has produced the FORTRAN PowerStation, a **32-bit high-level language compiler** that enables development of protected-mode MS-DOS-based applications that run at workstation speed. The product comes with Visual Workbench, a Windows-hosted integrated development environment that allows seamless movement between the compiler, editor, and debugger.

For More Information Write In No. 715

Micro Express, Santa Ana, CA, has unveiled a **multimedia portable PC** that features a 10" color VGA active-matrix TFT liquid crystal display with CCFT backlighting and 640 x 480 pixel resolution. Based on the i486DX 33-MHz cpu, the PC provides 4 MB of RAM, 256 K of RAM cache, a 200 MB IDE fast hard disk drive, a 3-1/2" high-density floppy disk drive, and a CD-ROM drive. The entire package, which includes a mouse, DOS 6.0, and Windows 3.1, costs $4999.

For More Information Write In No. 716

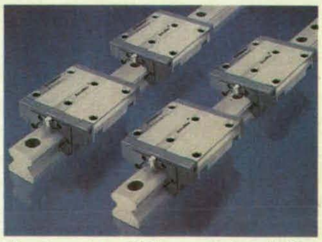


Handheld, microprocessor-based **infrared temperature probes** that plug directly into standard J or K thermocouple meters have been introduced by Raytek, Santa Cruz, CA. Suited for hazardous applications, the noncontacting Infra Probe (IP) thermometers provide ±1° resolution from -18 to 260 °C, with a 1 second response time. Both the IP-J and IP-K measure 180 mm x 30 mm x 50 mm and are powered by a standard 9V battery.

For More Information Write In No. 717

A **boron/graphite prepreg** formulated by Textron Specialty Materials, Lowell, MA, offers up to a 40 percent improvement in compressive, tensile, and flexural strength and a 30 percent higher modulus than boron/epoxy prepreg. Called Hy-bor™, the composite consists of small-diameter graphite fibers nested between 3- or 4-mil boron fibers in an epoxy matrix.

For More Information Write In No. 718



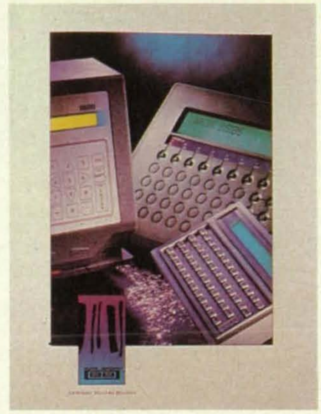
The AccuMax™ **linear recirculating roller bearing system** from Thomson Industries Inc., Port Washington, NY, provides twice the rigidity and load capacity of comparably-sized linear ball guide systems. Suitable for heavy industrial and precision machine tool applications, the system features continuously-crowned Arcuate™ races that eliminate skewing and scuffing caused by roller edge loading and roller taper.

For More Information Write In No. 719

Spectrum™, the first **full physics simulation tool** for the mechanical design automation industry, has been released by CENTRIC Engineering Systems Inc., Palo Alto, CA. Currently available for Silicon Graphics workstations, the software enables analysis of a product's structural, fluid, and thermal behavior during the design process. It includes an interface to SDRC and PDA design environments.

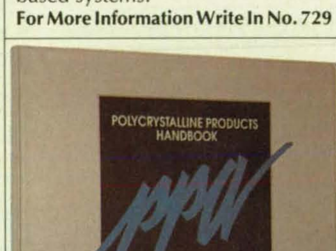
For More Information Write In No. 720

New Literature



A 12-page catalog from Burr-Brown Corp., Tucson, AZ, presents the LANpoint® Computer product line. Designed for automated data collection applications, LANpoint®, TIMEpoint™, and FACTORYpoint™ are rugged, compact DOS PCs with built-in interfaces for both Ethernet™ and bar code. The computers permit integration of complementary technologies such as bar code, magnetic stripe, RS-232 serial connections, and serial and digital I/O.
For More Information Write In No. 728

Spectrum Dynamics, Houston, TX, has published *Virtual World Builder*, a 96-page **virtual reality (VR)/synthetic digital environment (SDE)** products catalog and resource guide. Products from over 50 manufacturers include head-mounted displays, shutter glasses, gloves, and other 3D input devices; synthetic 3D audio products; six-degree-of-freedom position trackers; VR/SDE development software; graphics accelerators; interactive media systems; and integrated PC and SGI-based systems.
For More Information Write In No. 729



Polycrystalline Products Association, Dublin, OH, has published a 250-page **polycrystalline products** handbook. It includes sections on PCD and PCBN product guidelines and applications, CVD diamond products, and nomenclature.
For More Information Write In No. 730

Surface mount diodes are showcased in a new brochure from Microsemi Corp., Santa Ana, CA. Featured products include square and round end-cap MELF, epoxy DO-214AA & AB and DO-215AA & AB, SMDO-5, and new miniature Powermite™ packages. Three cross reference guides focus on rectifiers, zeners, and transient voltage suppressors, respectively.
For More Information Write In No. 731

Analogic Corp., Peabody, MA, has released volume two of its high-performance **PC/AT data acquisition** products catalog. More than 40 pages highlight hardware and software such as digital I/O cards, serial communications products, signal conditioning modules, and Windows-based software to ensure easy setup and integration of Analogic boards with a host PC. New products include the DCP5B and D-1000 series of signal conditioners for measuring and conditioning temperature, pressure, flow, and other analog signals.
For More Information Write In No. 732

Literature from Amoco Performance Products Inc., Alpharetta, GA, describes properties and applications of its eight high-performance **thermoplastics**. The polymers include Amodel® polyphthalamide, Udel® polysulfone, Mindel® resins, Radel® A polyethersulfone and Radel® R polyphenylsulfone, Torlon® polyamide-imide, and Xydar® liquid crystal polymers.
For More Information Write In No. 733

A four-color catalog from Sierra Instruments Inc., Monterey, CA, describes the company's line of **thermal mass flow meters and controllers** for air and process gases. Products illustrated include capillary-tube-type meters and controllers, insertion-type flow meters and averaging arrays, portable air velocity meters, and primary standard calibration systems.
For More Information Write In No. 734

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Ph.D candidate in materials engineering, graduate summer '93. Synthesis, processing, and manufacturing of ceramics, intermetallics, and composites. Experience: manufacturing environment; works metallurgist/quality assurance/technical manager. Commercial/government program management. Seek position in R&D, teaching, or technical management. Andrew Grebe, New Mexico Tech. Tel. 505-835-5595; Fax. 505-835-5630.
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MS in chemical engineering, MS in computer science with strong scientific and instrumentation background. Experience with IEEE 488, RS 232, IEEE 802.x interfaces between Macintosh, MS-DOS, and MS Windows computing systems. Work experience includes 13 years at SRI International, three patents in diverse fields of chemistry, sensor technology, and electrical interfaces. Strengths include C, C++, BASIC, FORTRAN, scientific visualization and analysis, ANOVA, ARIMA, least squares, and real-time filtering.
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MS honors graduate in materials engineering looking for an entry level position in materials research lab. Experience in intermetallics, combustion synthesis of materials, and shock loading. Use and care of SEM, DTA and familiar with ES&H issues in lab.
Box number 62A

Physicist/engineer with 11 years in sensor and measurement application and R&D. Project director/principle investigator responsible for physics, electronic, mechanical and software aspects from concept to market. Applied acoustic, optic, electromagnetic and nuclear principles to diverse problems. BS EET, math, physics, seven US patents, two patents pending, publications, Engineering Innovation Award, 1988.
Box number 63A

Ph.D in biomedical engineering. Six years of experience in research. Interested in a position related to model simulation of oculometer system, vision computation, biomedical signal processing, and biomedical instrumentation. Experience in electronics ckt, computer languages (Fortran, Basic, 8086-based Assembly, and MATLAB) and hardware, UNIX, PC-DOS, and statistics. Tel. 908-463-3883.
Box number 64A

Graduate professional architect with registration in two states and NCARB member. Have 20+ years of experience in all phases of design: administration, client-architect relationships, codes, construction, specification writing, cost estimates, production drawings and marketing. Worked extensively in industrial projects. Oil, plastic, paper and pulp, research labs and project management. Desire growth position, will relocate.
Box number 65A

Senior manager with 25 years hands-on development of microprocessor electronics and software for magnetic peripheral, imaging, printing, and medical products. Experienced concurrent engineering with emphasis on marketing and manufacturing implementation. Strong technical skills, excellent motivator, and demonstrated capacity to manage diverse development programs.
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Seeking a marketing or manufacturing position in the electro-optics industry. Over 20 years experience in both sales and manufacturing of high reliability components. 15 years in worldwide sales, five years as sales manager, two years as product manager. Strong skills in applications, technical writing, customer relations, and defining and locating new business opportunities. Willing to travel but not relocate from the Boston area. James M. Melnyk, 26 Harrison Circle, Rowley, MA 01969. Tel. 508-948-7278.
Box number 67A

Materials/metallurgical engineer. Ph.D in metallurgy. Experience in materials selection, testing, product development and specifying manufacturing processes. Expertise in failure analysis, corrosion control, quality control heat treatment, welding, structure/properties correlation, ferrous and non-ferrous alloys. Several publications. Seeks senior level position in R&D or manufacturing.
Box number 68A

Lead mechanical design engineer on both large and small production systems. 12 years experience in design, manufacture, and test of mechanical/electrical systems. Design experience includes hydraulic systems, sophisticated mechanisms, and electronic packaging. Skilled in structural analysis and design incorporating Total Quality principles and manufacture capability concepts. Proficient on IBM PC operating systems (DOS, UNIX) and software packages, FORTRAN, C, and BASIC programming.
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Graduate engineer with MS. 35 years of experience in structural analysis and test—stress, dynamics, material design. Very successful. I relish the difficult problems. Highly innovative, team-oriented, resourceful, self-motivated. Good communication skills. Much published. Seeking small manufacturing company doing high tech R&D. Independent of government business. Willing to relocate.
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High honors BSME graduate. Experience: mechanical design and thermal design. Currently design, specify, order, and inventory mechanical and electrical components. Strong skills in stress analysis, thermal analysis, and computer applications including AutoCAD, SDRC (solid modeling), Lotus, and Excel. Five years experience as an auto mechanic prior to graduation. Registered EIT (State of Illinois). Willing to relocate. Day tel. 708-938-0039; Eve. tel. 708-360-8590.
Box number 71A

Polymer chemist with extensive experience in applications development, formulation, compounding and processing of rubber and plastic materials. Materials include: natural rubber, polyisopropene, EPDM, nitrile, fluorocarbon, silicone, epichlorohydrin, TPE and engineering thermoplastics. Process equipment experience: internal mixers, extrusion, calendaring. Rheology test instruments: rheometers and viscometers. Willing to travel/relocate. Available immediately.
Box number 72A

To submit an ad for inclusion in this column, send a copy of your resume and a 50-word summary to: *NASA Tech Briefs*, 41 East 42nd St., New York, NY 10017, ATTN: Gregg McQueen.

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New Literature

Polymer Corp., Reading, PA, has published **fabrication guidelines for nylon, acetal, Ertalyte® PET-P, and high-performance thermoplastic machining stock** such as PEEK, Techtron™ PPS, Ultem®, and Torlon PAI rod and plate. Coolant information and suggested machining feeds and speeds for turning, drilling, and milling are provided.
For More Information Write In No. 727

A 136-page technical guide from NTE Electronics Inc., Bloomfield, NJ, highlights its UL- and CSA-recognized **electromechanical and solid-state AC and DC relays**, I/O modules and sockets, and accessories. More than 16,000 devices from 166 manufacturers are cross-referenced to the NTE line, which encompasses power relay, latching, PC mount, reed relay, automotive, time-delay, solid-state, I/O, and general-purpose modules.
For More Information Write In No. 725

A 52-page guide to selecting **specialty materials** is available from Carpenter Technology Corp., Reading, PA. The publication details approximately 400 alloys, including stainless steels, corrosion-resistant alloys, aerospace and high-temperature alloys, tool and die steels, nickel-copper alloys, gear and valve steels, thermocouple and high-nickel alloys, and magnetic, controlled-expansion, electrical, heating element, and resistance alloys.
For More Information Write In No. 721

A wide range of **analog-to-digital and digital-to-analog converters** are showcased in a catalog from Micro Power Systems Inc., Santa Clara, CA. It describes high-speed sampling, SAR, DAS, and multichannel A/D converters, and both current and voltage output D/A converters. New products include the MP3274, a fault-protected 12-bit A/D subsystem that can handle up to 32 analog input channels and output data to a microprocessor in serial or parallel data modes.
For More Information Write In No. 722

Interpoint Corp., Redmond, WA, has published a guide to **power supply reliability** for DC-DC converter users who design systems in which very high reliability is critical. Topics include Mean Time Between Failure calculations, qualification procedures, and field return data.
For More Information Write In No. 724

A technical note published by Micron Instrument Corp., Ronkonkoma, NY, explains the loading that different types of gearing transmit to drive-motor shafts and bearings. Designed to support development of loading equations for use in **gearhead selection**, it illustrates how motor bearing life can be drastically shortened if load-sizing calculations are not performed and the gearhead fails to match the motor's bearing capacity.
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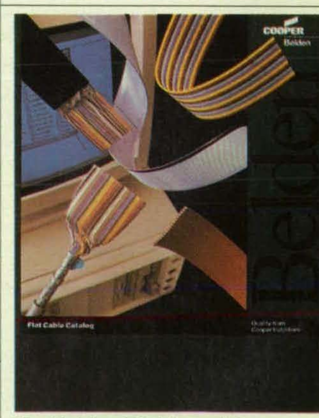

The Belden Division of Cooper Industries, Richmond, IN, has released a 52-page **flat cable** catalog. Featured product lines include Gray Ribbon, Ground Plane, Rainbow, Vari-Twist®, Ribbon Coax, MASSTER®(Round-To-Flat), Shielded Jacketed, and Shielded Data Link. Dimensions, physical characteristics, electrical specifications, and graphs illustrating attenuation and unbalanced crosstalk values are provided.
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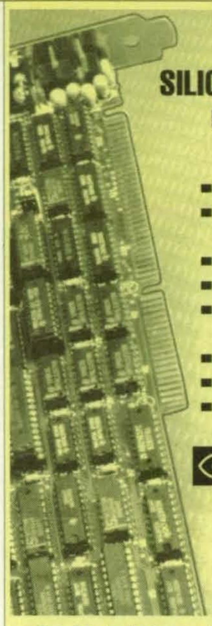

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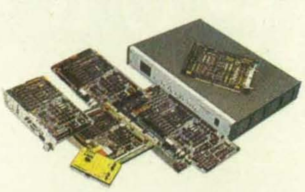

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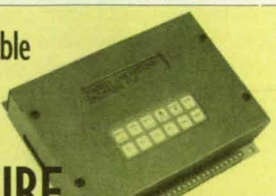

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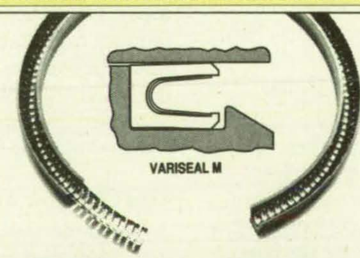

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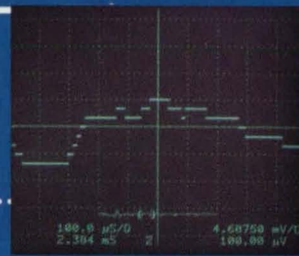

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